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IRRIGATION OF ALFALFA.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., July 15, 1909.

Sir: I have the honor to transmit herewith material for a bulletin on the irrigation of alfalfa, prepared by Samuel Fortier, chief of irrigation investigations of this Office. This material is based on the best irrigation practice of the arid region, and is intended primarily for the use of settlers under the large canal systems now under construction. It is therefore recommended that it be published as a Farmers' Bulletin.

Doctor Fortier wishes to acknowledge the receipt of notes on the irrigation of alfalfa from the following State agents and special agents temporarily employed by them for this and other purposes: Arizona, C. E. Tait, in charge, and C. G. Gillespie, special agent; California, F. W. Roeding, in charge, and R. C. Benson, Paul Baily, and Lee O. Murphy, special agents; Colorado and Wyoming, O. W. Bryant, in charge, and Fred J. Barnes, C. M. Wood, A. B. Collins, and George C. Kreutzer, special agents; Idaho, Elias Nelson and John Krall, special agents; Kansas, Don H. Bark, in charge; Montana, H. I. Moore, special agent; Nevada, Gordon H. True, in charge, and F. L. Peterson, special agent; New Mexico, B. P. Fleming, in charge; Oregon, A. P. Stover, in charge; Utah, W. W. McLaughlin, in charge, and L. M. Winsor, special agent; Washington, S. O. Jayne, in charge.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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INTRODUCTION.

Experience in the growing of alfalfa for more than two thousand years shows that it thrives best in the soil and climate of arid and semiarid regions. The abundant sunshine, the warmth, and the deep, rich soil prevailing throughout the western half of the United States seem to be well suited to its requirements, and over half a century's experience has shown that there is comparatively little cultivable land in the West on which it can not be grown. One finds the same varieties flourishing in Imperial Valley, California, 100 feet below sea level, and maintaining a sturdy growth on the San Luis plains of Colorado, 7,500 feet higher. Alfalfa makes a remarkable growth in the warm sunshine of Arizona, yet it is rarely injured by cold in Montana.

One can not well overestimate the importance of alfalfa to western farmers. The alfalfa field and the alfalfa stack provide the best means of protecting stock against enormous losses by starvation when the excellent pasturage available throughout the greater part of the year fails either through drought in midsummer or by being covered with deep snow in midwinter. A single ton of alfalfa may save the lives of many head of stock by providing feed during short periods of cold, stormy weather. Alfalfa can not be excelled as a preparatory crop on soils that have long been unproductive. Likewise, it maintains the fertility of soils naturally rich in plant food, and if used as a base of rotation makes possible abundant crop yields of various kinds. In 1906 the chemist of the Colorado Experiment Station [a] estimated the fertilizing value of the stubble and roots of mature plants at $35 per acre when measured by the commerical value of artificial fertilizers on the market. Moreover, the yields are exceptionally high when irrigation, favorable climatic conditions, and proper treatment are combined. Seven tons of cured hay at three cuttings are obtained from the best fields of Montana, while frequently 9 tons in five cuttings are harvested in California. This large tonnage, together with its high feeding value and the fact that it is consumed by practically all farm animals, makes it not only a convenient and useful crop to the grower, but a highly profitable one as well.

[a] Colorado Sta. Bul. 110.

Notwithstanding its present importance and great value in irrigation farming, the profits on the area now in alfalfa can be greatly increased if more care and skill are exercised in growing it. The western irrigator has seldom been able, financially, to dig his ditches and prepare his fields in such a way as to insure the most efficient irrigation and the highest profits. In consequence, valuable water is wastefully applied to land that is in no fit condition to be irrigated. On the large acreage in irrigated alfalfa this amounts to an enormous loss. This fact, considered in connection with the importance of this crop, the rapidly increasing area devoted to its growth, and the large number of farmers who are settling in the West and who will be for years dependent in a large measure on alfalfa for a livelihood, would seem to warrant the collection and publication of any information designed to improve the present practice.

As its title implies, this publication deals with but one feature, that of irrigation, and its scope is necessarily limited to irrigated lands. There has been no attempt to present or discuss at any length other phases of the general subject of alfalfa growing,[a] and wherever mention has been made of these it has been only to show their relationship to irrigation.

In the examination of alfalfa fields and the collection of the data necessary for this publication, advantage was taken of the organization of the irrigation investigations of this Office, which is well adapted for such a purpose. Through the State and Territorial agencies of that division and through cooperation with the members of State experiment stations and the State engineers it was possible to obtain with a high degree of accuracy the conditions and irrigation practice with reference to this crop throughout the entire arid region.

IRRIGABLE LANDS ADAPTED TO ALFALFA.

Perhaps the most essential conditions for the production of alfalfa are abundant sunshine, a high summer temperature, sufficient moisture, and a rich, deep, well-drained soil. All of these essentials, save moisture, exist naturally in the arid region of the United States, and when water is supplied it makes the conditions ideal. Although alfalfa can be successfully grown under a wide range of soil conditions, yet all western lands are not equally well adapted to its growth. For this reason those who are seeking such lands with a view to their purchase should first make a careful examination of the character and depth of the soil, its behavior when irrigated, the slope and evenness of the surface, the presence of injurious salts, and the facilities for drainage.

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[a] These are treated in U. S. Dept. Agr., Farmers' Bul. 339.

One of the best indications of the character of the soil is the native vegetation. When sagebrush, buffalo grass, or cactus is found on a tract it is reasonably certain that the soil is fertile, easily tilled, and well drained. On the other hand, the presence of greasewood, saltwort, salt weeds, or similar plants is indicative of a heavier soil, less easily cultivated and irrigated, and containing more or less of the injurious salts usually grouped under the common name of alkali.

In arid regions most cultivated plants are deep rooted. They draw their supply of plant food and moisture from considerable depths, and the deeper the soil the larger is the feeding ground for the roots and the greater is the capacity to store water. The presence of any impervious stratum lying between the first and fifth foot prevents deep rooting and the storage of moisture. A hard stratum lying between the fifth and tenth foot is likewise injurious, but to a less extent. The character of the subsoil may be readily determined by boring holes, with a suitable soil auger similar to that shown in figure 1, to a depth of 10 feet, if necessary, and taking samples of soil at different depths. It will be possible usually to find under irrigation in near-by fields soils similar to those being examined, but if this is not possible a trial may be made on a small scale to determine how the soil acts under irrigation. In general, sandy loams irrigate well; clay is hard to cultivate when wet, does not absorb water readily, and bakes and cracks when drying; while a soil which is too sandy will not retain sufficient moisture to maintain crops.

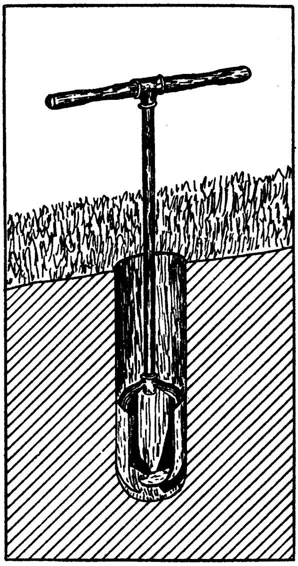

FIG. 1.—Soil auger.

The most favorable condition for irrigating is a smooth surface, with a uniform slope of 10 to 20 feet to the mile. Such land costs little to put into shape for the spreading of water over it, and the slope insures good drainage. Sometimes the land is cut up by ravines which increase the labor and cost of putting water upon it, or it may have too much or too little slope. In other cases it is full of buffalo or hog wallows which are difficult to bring to an even grade. If land which is naturally smooth on the surface and of the right slope costs $5 per acre to prepare for irrigating, hog-wallow land may cost $15. Besides, some hog-wallow land is inferior in quality, frequently being charged with injurious salts.

Lastly, good drainage is essential for a permanently productive irrigated farm. It is practically impossible to supply crops with sufficient water for the best growth without applying so much that some will seep into the subsoil. Unless this can flow away the level of the ground water will rise until it comes near the surface and drowns out crops, and perhaps cause an accumulation of alkali. If the natural drainage is not good it must be supplied artificially, but this need not be done until a few crops have been raised, for the reason that it is not possible to tell until after irrigation where the drains should be placed to drain the land most effectively.

The frequent failures to get a good stand of alfalfa in the humid portions of the United States have led some writers on this subject to prescribe within somewhat narrow limits where and under what conditions this forage plant can be grown successfully. That this view is not correct as regards the irrigated portion of the United States is amply shown by the fact that it is grown successfully in every State and Territory of the arid region, in localities which are not only widely separated but possess many radical differences in the way of rainfall, temperature, altitude, topography, and soil.

THE REMOVAL OF NATIVE VEGETATION.

In arid America few places are so barren as not to produce plants of some kind, and the first step in preparing land for irrigation is the removal of this native vegetation. When this consists of native grasses, low cacti, or small bushes they can be plowed under or removed without much extra expense, but when it consists of large sagebrush, mesquite, or greasewood, the cost is high and the task of removing it may require special implements. Of all the desert plants sagebrush is the most common. Formerly the grubbing hoe, or mattock, and plow were the only implements used to remove this bush. Breaking down the branches and then digging out the roots before attempting to plow proved laborious. By this process the cost of grubbing, gathering the brush into piles, and burning varied from $2 per acre in light sage to $5 per acre in heavy sage. Of late, farmers who are well provided with work teams greatly expedite the work and reduce the amount of manual labor by first dragging a railroad rail or heavy timber over the sagebrush. This work can be done best when the ground is frozen. If only two teams of two horses each are available, one rail will suffice, but with six, or, better still, eight horses, four at each end, two railroad rails may be bolted together. If iron rails can not be had, two large logs chained together make a good substitute. In railing brush, as it is termed, the rails are dragged at least twice over the same strip, but in opposite directions. The few stumps which remain are

then grubbed out by hand or left to be plowed out and the brush raked into windrows and burned. A brush rake may be made of a 6-inch timber 12 feet long, by boring 2-inch holes through the timber, 10 inches apart, and inserting in each a wooden tooth about 3 feet long. The rake is then fastened by two joists to the rear of a wagon to which a team is hitched. In the San Joaquin and Imperial valleys of California the railroad rail is bent in the form of a V, but it is a question if this form has any advantages over the straight rail. A more effective implement for light brush is sketched in figure 2. From 8 to 12 horses are hitched to it and 20 acres may be cleared in one day. In Kern County, Cal., a 6 by 12 inch timber, 24 feet long, shod with steel, is preferred. The steel shoe projects

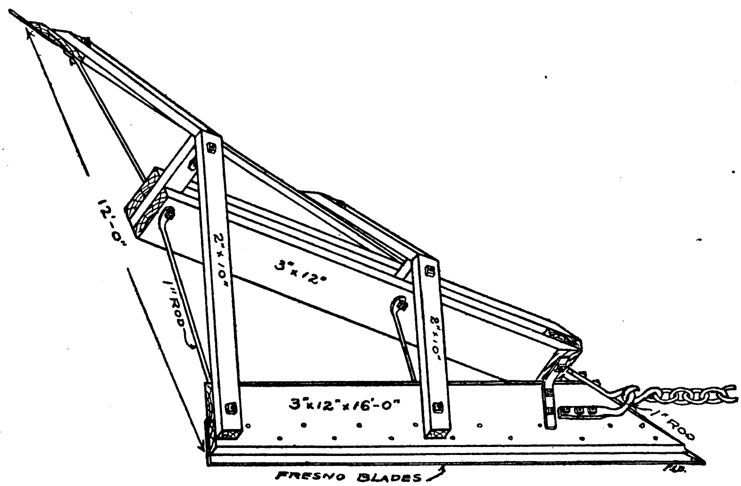

FIG. 2.—Sagebrush grubber used in clearing land near Riverton, Wyo.

about half an inch and a board on the back, similar to that of a buck scraper, serves to keep it in position. A team is hitched to each end, crossing the field and returning on the same track. The cost of the removal of sagebrush by means of teams and a minimum amount of hand labor runs all the way from $1.50 to $4 per acre, depending on the character and extent of the growth.

In the Imperial Valley of California, the Rio Grande Valley of New Mexico and Texas, and in parts of Arizona, the mesquite tree is quite troublesome to remove. This usually has to be grubbed out by hand and the cost varies from $5 to $40 per acre, depending on the number and size of the trees. Oscar Snow has 600 acres in alfalfa in the Mesilla Valley, New Mexico. In its natural state the land was covered with a dense growth of tornillo, mesquite, and shad scale. He states that it cost him $40 to $50 per acre to cut the brush, grub out the roots, grade the land, and seed it to alfalfa.

The usual price paid for grubbing out mesquite bushes in Salt River Valley, Arizona, is 30 cents per tree and the cost may run as high as $100 per acre. The larger trees have usually some value as firewood and fence posts.

Mr. Hubbard, of Weiser, Idaho, rids the raw land of sagebrush and plows it to a depth of 8 inches before grading and leveling the surface. Whenever possible, this work is done in the fall, and early the following spring the tract is thoroughly disked and harrowed. He prefers flooding the tract before seeding in order that the water may show up the low as well as the high places and also to insure ample moisture for the speedy germination of the seed. When the surface dries out sufficiently to pulverize after the harrow, it is seeded. In this part of Idaho the cost per acre for removing sagebrush varies from $2.50 to $4; for plowing, $2.50 to $3; disking, 50 cents to 75 cents; harrowing, 35 to 50 cents. Grading and leveling are discussed under another heading.

In localities covered by native grasses, nothing more is necessary than plowing and thorough cultivation. The native grass lands of Montana are usually plowed 2 to 5 inches deep in the fall. In the spring the surface is double-disked, perhaps cross double-disked, harrowed, and leveled, and then seeded to grain rather than alfalfa, in order to properly prepare the surface of the ground for the later crop.

The cost of plowing new land in Kern County, Cal., where the surface is covered with low sage, wheat, and wire grasses, runs from $2 to $4 per acre, depending chiefly on the depth of plowing, which is usually more than 4 inches and less than 10 inches. On the extensive holdings of Miller & Lux traction engines are used to operate gang plows, followed by harrows. By this means, it is claimed, the cost can be reduced to between 75 cents and $1 per acre.

In all the older irrigated sections of the West alfalfa usually follows some other crop. If preceded by grain the stubble is first pastured, preferably by sheep, plowed in the fall to a depth of 7 to 10 inches, and then allowed to lie until the following spring, when it is disked, harrowed, and seeded.

PREPARATORY CROP.

Experience has shown that it is difficult in the course of six months or a year to secure a good stand of alfalfa on raw land that has been covered by a desert growth. This is true particularly of rough, uneven land on which crop rotation is not to be practiced. It is likewise true of land thickly covered with brush. It has been found impracticable in most localities to secure a smooth, well-graded surface where fresh roots interfere with the proper use of all grading and leveling implements. The same is true of hog-wallow land, where considerable soil has to be removed from the high places and deposited in the low

places. It takes time and a second preparation of the surface before fields of this character can be put in good condition for the growth and irrigation of alfalfa. If crop rotation is to be followed the necessity for a preparatory crop is not so urgent, since the alfalfa will soon be plowed under to give place to another crop. In northern Colorado, where alfalfa usually follows either potatoes or sugar beets, the surface is not plowed, but merely harrowed or disked in the spring just before seeding. If the surface is uneven, it is smoothed and leveled by means of a float or drag before the seed is put in. In southwestern Kansas it is likewise considered best to plant alfalfa after some cultivated crop which has held the weeds in check. The land is plowed in the fall to a depth of 6 inches, double-disked in the spring after the weeds have started, and is subsequently harrowed. In the vicinity of Los Banos, Cal., new land is almost invariably sown to barley or corn for two seasons before seeding to alfalfa. In Utah wheat or oats is preferred as a preparatory crop. The chief purpose of all such preparatory grain crops is to allow fresh roots of the original plant covering to decay, filled-in spots to settle, high places denuded of the upper layer of soil to weather, and in general to prepare a well-pulverized seed bed in a smooth, well-graded field.

METHODS OF IRRIGATING ALFALFA.

The methods of applying water to alfalfa differ widely because of diversity in soils and subsoils, in climate and topography, in the nature of the water supply, the size of the farm, the amount of money available for preparing the land for water, the prevailing crops grown, and the early training and environment of the irrigator. The standard methods have been grouped under the following heads, namely, the border method, the check method, flooding from field laterals, furrow irrigation, and other less common methods, with various modifications of each.

In passing it may be said that the usual order is to locate and build the farm ditches first and prepare the land afterwards. In this bulletin it has been deemed best to describe the methods in use and then to consider the location and construction of farm ditches. After one has a general knowledge of the various ways of applying water and of the size and character of the ditches required for each method he is in a better position to understand the proper methods to adopt in building farm ditches. This subject will therefore be treated separately under its own heading.

THE BORDER METHOD.

Essentially the border method consists of the division of a field or tract into long, narrow strips or lands by low flat levees which usually extend in the direction of the steepest slope and confine the water to

a single strip. The bed of each strip is carefully graded to a uniform slope, although the slope may change to conform to the contour of the natural surface. The water to irrigate each strip is taken from the head ditch extending across the upper edge of the field, and is controlled by an outlet box or border gate, although the gates are sometimes omitted to save in first cost of preparing for irrigation. Check gates, canvas dams, or metal tappoons are used to hold up the water in the head ditch to cause it to flow into the borders.

This method is confined chiefly to the irrigation of alfalfa and grain, and in its various modifications is used extensively in Arizona, California, and, to a less extent, in Idaho, Montana, and other Rocky Mountain States. It can be used best under canals which deliver water to users in large streams, since the smallest head that can be applied successfully is seldom less than 2 or 3 cubic feet per second,

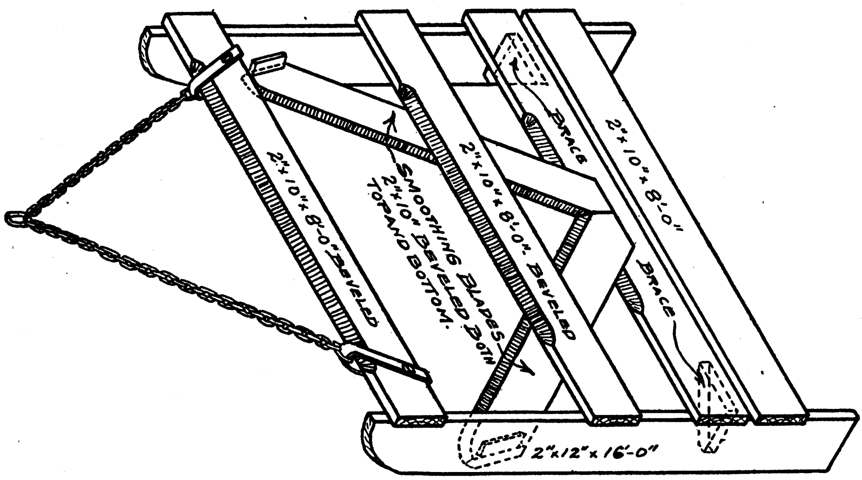

FIG. 3.—Levee smoother made by H. I. Moore.

but heads of 5 to 10 cubic feet per second are the rule. It is adapted especially to light, open soils, into which water percolates rapidly, as the use of a large stream confined between borders makes it possible to force water over the surface without great loss by percolation.

On the university farm at Davis, Cal., the borders or lands average about 50 feet wide by 900 feet long. Each levee has a base 7 feet wide and is 12 inches high, when newly made, but settles to about 10 inches before the first crop is harvested. The bed of each strip is leveled crosswise and slopes regularly from top to bottom. In preparing the surface of this field, the barley stubble was burned, then the soil was disked and roughly graded. The location of each border was marked out either by a drag or by making a furrow. Sufficient earth to form the border was obtained by skimming the surface with scrapers. The scraper teams began next to the head

ditch and worked down. They crossed and recrossed the field at right angles to the borders, and as a scraper passed a border marking it was dumped. Each scraper width of the borders was made up of two loads, but the last load overlapped the first by half the width of the scraper. The surface of each border was then leveled to within 0.1 or 0.2 foot of accuracy. The levees when first built were rough, irregular, and steep. They were cut down to a uniform grade by a homemade device called a planer, shown in figure 3.

In Imperial Valley, California, a 40-acre tract is divided in 22 lands each 60 feet wide and 0.25 mile long. When the slope is too steep the lands run diagonally across the tract. In order to lessen the first cost the material for the borders, instead of being scraped from the high portions of the lands, is taken from the sides of the borders. This creates hollows in which water may collect, makes the mowing and raking more difficult, and frequently lessens the yield. Such borders may be made by the use of the plow and ridger (fig. 4). In this method a narrow strip is first plowed and then the ridger, drawn by a number of horses, forms the loose earth into a ridge. The cost per acre for preparing the land by the border method in this valley varies all the way from $5 to $20, depending on the character of the native vegetation and the size and number of the hummocks. When creosote bushes and mesquite trees are surrounded by wind-driven sands, the cost may run as high as $40 per acre.

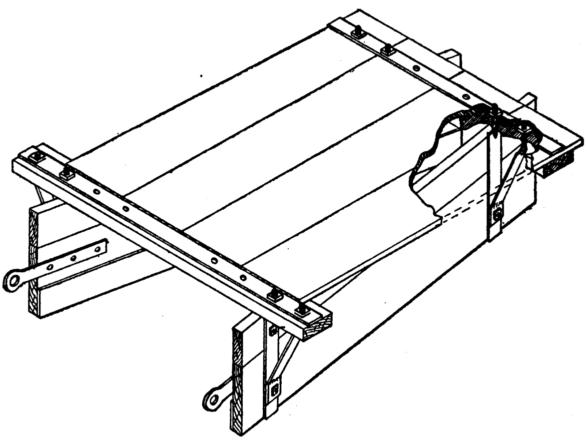

FIG. 4.—Adjustable ridger.

In Salt River Valley, Arizona, the customary method of preparing the land for alfalfa is to remove the brush, plow the high places, and roughly level the surface with suitable scrapers. Then the borders are marked off from 30 to 50 feet apart. The spacing depends on the porosity of the soil, the configuration of the land, and the head of water available. After forming rough borders by means of four plow furrows thrown together to form a ridge, a disk or spring-tooth harrow is run lengthwise of the lands. The borders are then crowded with a V crowder and usually a leveler is run transversely to the

borders to round them off. The land then receives a heavy irrigation and when dry enough to work is again disked or harrowed and seeded. Such borders when first made have a base of about 3 feet and a height of 1 foot, which settles to about 9 inches. The length of the borders or lands varies from one-eighth to one-fourth mile.

The farmers on the Roswell Bench on the south side of the Boise River in Idaho make the levees 66 feet apart and 300 to 1,300 feet long, depending chiefly on the topography of the land. The land is first leveled with scrapers, then plowed and harrowed, after which the borders are marked off and thrown up by plowing two to four furrows with a heavy plow. Before seeding, a homemade planer is dragged lengthwise and crosswise of the lands in order to fill up the hollows by cutting off the high places. The cost of preparing land in this way and seeding varies from $10 to $30 per acre, depending upon the roughness of the surface.

One of the great advantages of this method is that it enables one man to use a large stream of water and irrigate a large area with a minimum of labor. The size of streams used in the Rillito Valley in Arizona varies. A head of about 100 miner's inches is turned into a plat of land 30 feet wide, and takes one to three hours to reach the lower end, 660 feet distant. Two men working twelve hours each, with this head of water, will irrigate in twenty-four hours 12 to 15 acres, at a cost of 20 to 25 cents per acre for each watering. In the extensive alfalfa fields belonging to the Butterfield Live Stock Company, of Weiser, Idaho, the head ditch has a capacity of 150 to 500 miner's inches, divided into three or four streams, and permitted to flow down as many lands until the soil is moistened to a depth of several feet. Each field receives three such waterings in a season. On the alfalfa fields in Yolo County, Cal., the natural slope of the land is about 1 foot in 400. On the shorter lands the head used is seldom less than 6 cubic feet per second, but three and four times this quantity is often applied to the longer lands. On fields well laid off, with good border gates and border levees, two men can irrigate 20 to 40 acres in twelve hours, the area within these limits depending chiefly on the size of the irrigating head. In Imperial Valley, California, the size of the head used varies from 50 to 600 miner's inches. In using a head of 500 inches it is customary to divide it among five lands. With such a head it is not unusual for two men working twelve-hour shifts to irrigate 80 acres in twenty-four hours.

THE CHECK METHOD.

The essential features of the check method of irrigation consist in surrounding nearly level plats of ground with low levees, and in making provision to flood each by means of a ditch and check box or

gate. The inclosed spaces may be laid out in straight lines in both directions, thus forming with their levee borders a series of rectangles, or the levees may follow more or less closely the contour lines of the natural surface of the ground, thus forming contour checks. The most favorable conditions are a light, sandy soil on a comparatively even slope of 3 to 15 feet to the mile, abundantly supplied with water. This method is also used on heavy soils, where it is necessary to hold the water on the soil to secure its percolation to the desired depth.

In California not only does the form of the checks vary, but their size as well, some of the smaller being less than one-half acre in area, while some of the larger contain more than 10 acres.

In the Modesto and Turlock irrigation districts the surface of the land under ditch slopes about 5 feet to the mile, and is too uneven to be irrigated without being leveled first. The unevenness consists in swales, hog wallows, and mounds. The land is surveyed first either by an engineer or by the owner. In the latter case use is made of a carpenter's level, with peep sights, mounted on a tripod (fig. 5). The long side of each check should be on the flat slope and the short side on the steep slope. A fall of 3 to 5 inches between adjacent checks is preferable to either more or less. Usually the width of checks can be so adjusted as to permit of this difference in elevation. The length of each rectangle will depend on the slope in that direction as well as the location of the supply ditches. The field should be laid out in such a way that the levees may be built with the least handling of dirt. Rectangular checks possess many advantages over irregular contour checks, but if much of the better quality of surface soil has to be removed in order to build the former, the advantages may be more than outweighed by the damage caused by grading and the extra cost.

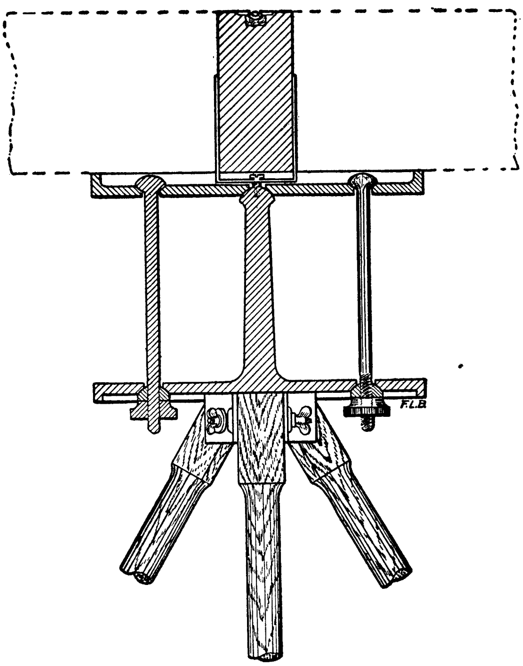

FIG. 5.—Carpenter's spirit level attached to a tripod.

Figure 6 shows in outline the rectangular checks, supply ditches, and check boxes on the farm of T. K. Beard, east of Modesto, Cal. Mr. Beard plows the land in the early spring to a depth of 6 inches with a 4-gang plow. During the summer the checks and ditches are built in a sort of rough way, no effort being made to level the floor of the checks or to smooth the levees and ditch banks. It is then heavily irrigated, and after the soil is sufficiently dry the floor of each check is carefully leveled and the levees trimmed and smoothed. For the latter purpose the grader shown in figure 7 is preferred. One passage of this grader across the top of each levee and once along each side reduces the levee to a base of 14 feet, and a height of 8 inches on the high side and 10 inches on the low side.

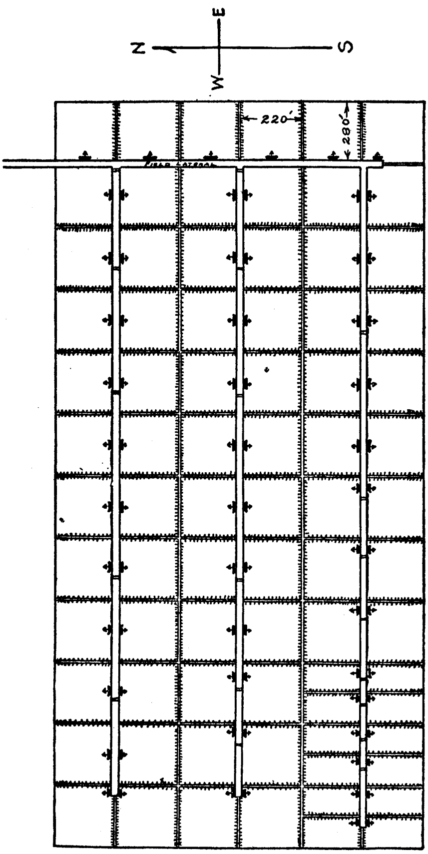

FIG. 6.—Laying out rectangular checks on farm of T. K. Beard, Modesto, Cal.

On the west side of the San Joaquin Valley the land to be seeded to alfalfa is almost invariably formed into contour checks. A common arrangement is that shown in figure 8. Here the supply ditches are intended to be about 600 feet apart, and levees are built midway between. The sides of the checks conform in a measure, but not exactly, to the natural contours, having a difference in elevation of 0.3 to 0.4 foot. The average area of a check is half an acre. In 1908 prices were obtained on the cost of preparing land in contour checks and seeding to alfalfa. The average cost on 2,067 acres of comparatively smooth grain land was $11.46 per acre. Across the river in Modesto and Turlock districts, where rectangular checking is more common and where the natural surface is more uneven, the cost was estimated at $17.50 for contour checks and $19 for rectangular checks. These latter figures included ditching, but excluded the cost of seed and seeding.

In the Modesto and Turlock irrigation districts the feed ditches are designed to carry large heads of 10 to 20 cubic feet per second.

These large heads are used by the farmers in turn for short periods of time, depending upon the acreage served. In the smaller checks a head of 5 cubic feet per second will suffice, and if 20 cubic feet per second are available four checks may be irrigated simultaneously. This head flowing on a check containing 1 acre would cover it to a depth of about 5 inches in one hour. A part of the water so applied is always lost by evaporation, but the balance percolates into the soil to furnish moisture to the plants. The skillful irrigator begins with the highest checks and works down for the reason that all waters which escape through the gopher holes or broken levees may be then applied to dry checks. To reverse this rule might result in overirrigating the lower checks. The average cost of irrigating for the season where proper check boxes are inserted is about 60 cents an acre.

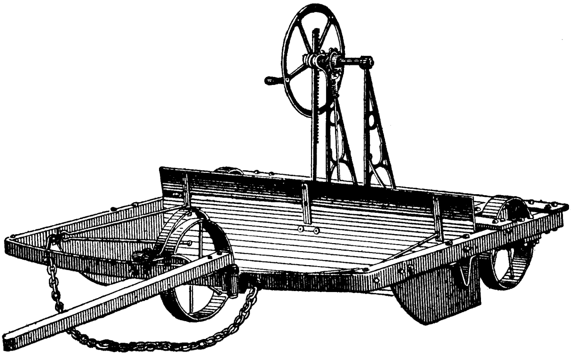

FIG. 7.—Grader.

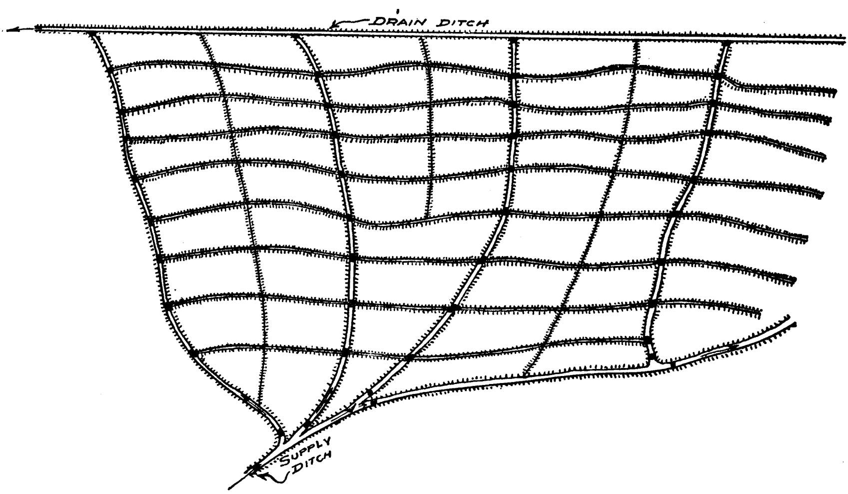

FIG. 8.—Laying out contour checks.

On the west side of the San Joaquin River each of the irregular compartments contains 1 to 3 acres, averaging about 2 acres. Few permanent wooden check boxes are used. The water is checked up by dams of coarse manure, and an opening is made in the levee bank

with a shovel to admit the water. The lack of suitable boxes to control the water passing from the feed ditch into each check and the use of smaller heads greatly increase the cost of irrigating over that of the Modesto and Turlock districts. In the latter the cost for the season was estimated at 60 cents per acre, while in the former the estimate is 90 cents for each watering.

The chief advantage of the check method is that one man can attend to a large volume of water and can irrigate 7 to 15 acres in ten hours, making the cost of applying water less than by any other method except the border method. To counterbalance this important gain, there are several disadvantages which western farmers ought to consider. These are the removal of a considerable quantity of surface soil to form the levees, which frequently decreases the yield on the graded spots; the extra cost of preparing the land; the damage done to farm implements in crossing levees; and the fact that this method is not well adapted to a rotation of crops.

THE FLOODING METHOD.

Flooding from field ditches or laterals is still the most common method of applying water to the arid lands of western America. In the States of Colorado, Montana, Wyoming, Utah, and to a large extent in Idaho, alfalfa, clover, native meadows, and grain are irrigated in this way. This manner of wetting dry soil originated, it is believed, in the mountain States, and the past half century has witnessed a gradual evolution of this plan, so that now it has not only become firmly established, but is regarded as the best suited to the conditions under which it is practiced. It can be profitably used on slopes that are too steep for other methods. Fields having a firm soil and a fall of 25 feet to 100 feet have been flooded successfully. From this extreme the slope may diminish to less than 0.1 foot in 100 feet. Its cheapness is another feature which recommends it to the farmer of limited means. Ordinary raw land can be prepared for flooding at an expense of $2 to $5 per acre. Again, it is adapted to the use of small water supplies. In the mountain States the irrigation systems have been planned and built to deliver water in comparatively small streams for use in flooding or in furrows, and water users should be certain that the larger volumes required for checks and borders can be secured before going to the expense of preparing their fields for either of those systems.

In grading the land for this particular method it is not customary to make many changes in the natural surface. Only the smaller knolls are removed and deposited in the low places. An effort is made always, however, to make the farm laterals fit into the natural slope and configuration of the tract to be watered so as to bring

the water to the high places. On steep slopes the laterals may be less than 50 feet apart; on flatter slopes they may be 200 feet or more apart. Whatever the spacing it is always desirable to have the slope between them as nearly uniform as possible. When the land in its natural state is uneven, the grading can be done best by a grader of the kind shown in figure 7, page 19, or a scraper of the kind shown in figure 9. When these are used, it is often advantageous to make use of some such implement as the grader shown in figure 10 for the final smoothing and grading. If the field in its natural state is comparatively smooth and level a homemade drag or leveler, as shown in figure 11, serves the purpose fairly well.

The distribution of the ditches on the field varies too widely to admit of presenting a standard plan, but figure 12 shows an arrangement of field laterals common to the mountain States. A supply ditch, AB, is built on one side and laterals, CD and EF, branch out from it on a grade of 0.5 to 0.75 inch to the rod. These laterals are spaced 75 to 100 feet apart and are made with double moldboard plows, either walking or sulky. Figures 13 and 14 illustrate other common arrangements in use in northern Colorado.

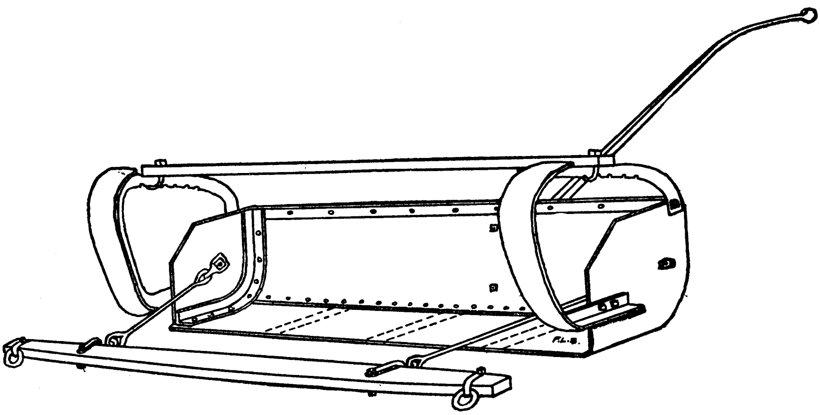

FIG. 9.—Scraper.

In the vicinity of Fort Collins, Colo., the main lateral is built to the highest corner of the field to be irrigated and the smaller laterals extend out from it, spaced 75 to 225 feet apart, the spacing depending on the slope of the ground and the coarseness of the soil. The size of the laterals is governed by the head which may be had, but on steep slopes and on soil that erodes readily, small heads are best. Around Berthoud, Colo., the land is naturally of uniform, even slope, and little grading has been necessary. Heavy timber or iron drags are used to smooth the surface after plowing so that the water will spread evenly. These are built in various ways and out of whatever

material happens to be available on the farm. Worn-out steel rails, such as have been removed from a railway, are often used, two rails being fastened together about 30 inches apart. A team is hitched to each end and the driver rides on the drag. Once over a field with

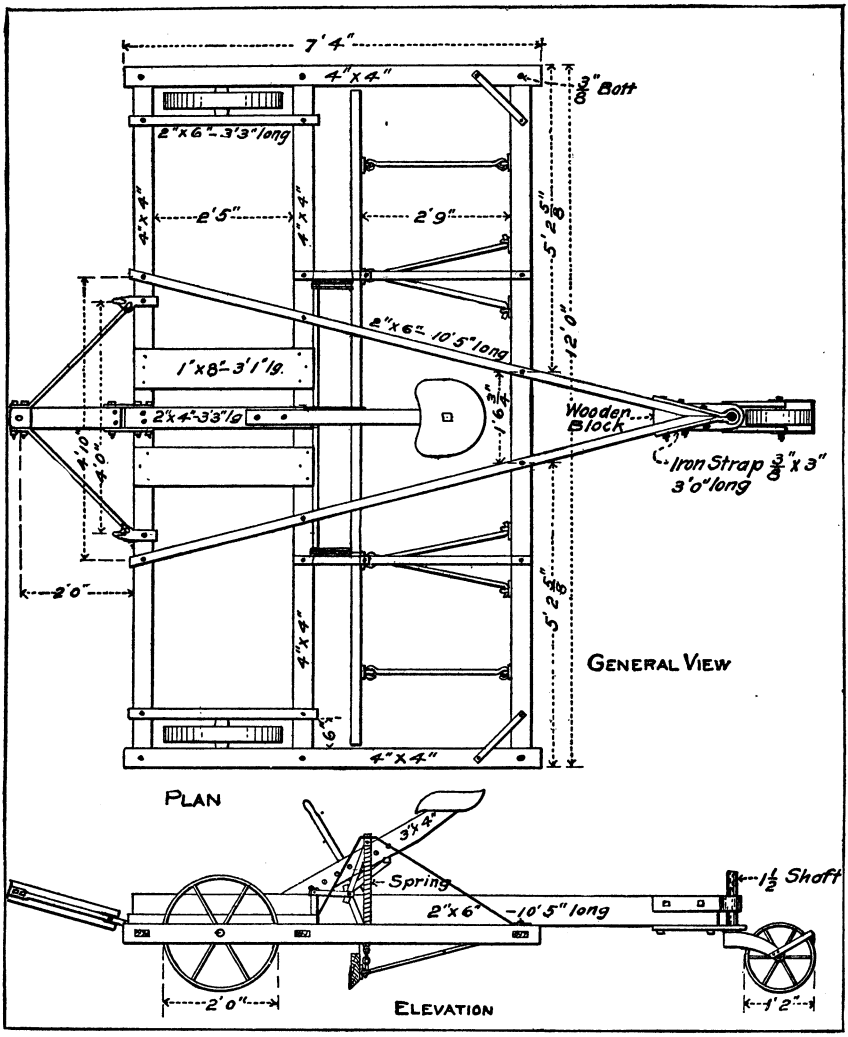

FIG. 10.—Leveler used in Gallatin Valley, Montana.

a drag of this kind is usually sufficient to make the surface quite uniform and smooth. The proper location for field laterals is usually evident to the irrigator without the use of surveying instruments, though in fields where the fall is slight it is often necessary to have a topographical survey made and the laterals located by an engineer. Field laterals are always so located that they cover the highest parts

of the field and their distance apart in alfalfa varies from 10 to 20 rods.

The head required for flooding from field laterals in northern Colorado varies from 2 to 3 cubic feet per second and is divided

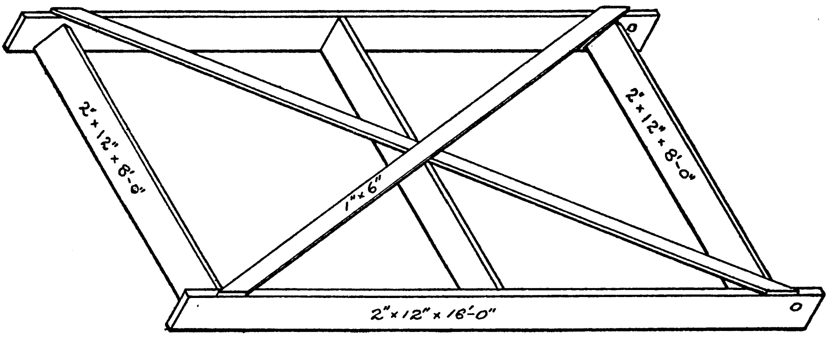

FIG. 11.—Homemade drag or leveler.

between two or three laterals. Canvas or coarse manure dams are used to check the water in the laterals and to force it out over the banks and down the slopes of the fields. In less than three hours the upper foot of soil is usually thoroughly moistened. To apply one watering in this way costs from 15 to 30 cents an acre.

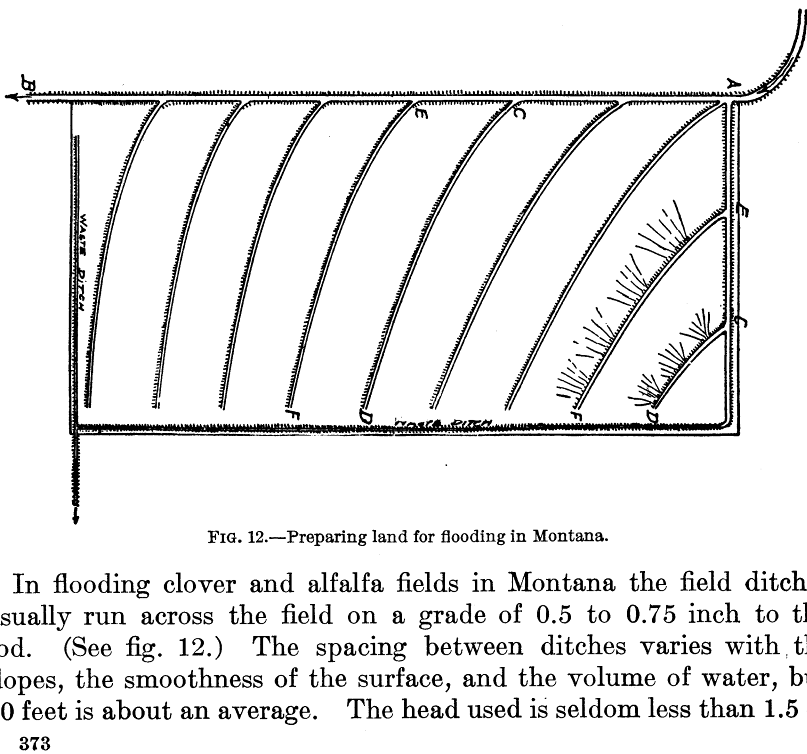

FIG. 12.—Preparing land for flooding in Montana.

In flooding clover and alfalfa fields in Montana the field ditches usually run across the field on a grade of 0.5 to 0.75 inch to the rod. (See fig. 12.) The spacing between ditches varies with the slopes, the smoothness of the surface, and the volume of water, but 80 feet is about an average. The head used is seldom less than 1.5 or

more than 4 cubic feet per second, the larger heads being divided between two or three ditches. In irrigating, a canvas dam is first inserted in each ditch or set of ditches, 75 to 100 feet below the head. The water is then turned into each channel and flows as far as the canvas dam, by which it is checked and as a consequence rises and flows over the low places of the lower bank or through openings made with the shovel. When these small tracts have been watered, the canvas dam is raised, dragged down the lateral 75 to 100 feet, and again inserted in the channel to serve the next tract. Manure dams sometimes take the place of the movable canvas dams. Some time before a field is to be irrigated and after the ditching is done coarse manure is placed in small heaps within each ditch channel at suitable intervals and each heap is covered with earth on its upper face

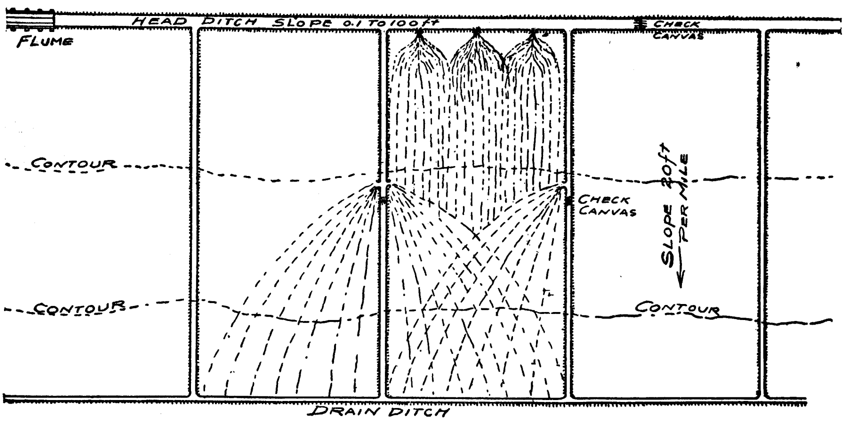

FIG. 13.—Flooding from head ditches in northern Colorado.

to a depth of 1 to 2 inches. When this check has served its purpose it is broken and the water flows down until stopped by the next check. In some instances permanent wooden check boxes are inserted in each lateral, while in others the canvas dam is used. The thorough irrigation of 4 acres is considered a good twelve hours' work for one man. By the use of 100 miner's inches, two men can irrigate 7 to 10 acres in twenty-four hours at a cost of 45 to 65 cents per acre.

In the Salt Lake Basin the heads of water used by the irrigators of alfalfa vary considerably with the flow of the streams. In spring heads of 4 to 6 cubic feet per second are common, while later in the season when the streams are low they are reduced to 1 to 3 cubic feet per second. A field is usually divided into strips 200 to 500 feet wide by laterals extending across it (fig. 12). A permanent wooden check box or a canvas dam is inserted in the main supply ditch below each cross ditch, causing the water to flow into the cross ditch. From there it is spread over the surface through small openings in the ditch

bank and any excess water is caught up by the next lower ditch. In this way each ditch serves a double purpose, acting as a drainage channel for the land above it and as a supply channel for the land below it.

In summarizing the advantages of the flooding method, it may be said that in first cost it is one of the cheapest, it is adapted to the delivery of small volumes of water (50 to 100 miner's inches) in continuous streams, it is particularly well adapted to forage and cereal crops of all kinds, the top soil is not removed from the high places to fill up the low places, and firm soil, although it be on steep and irregular hillsides, can be successfully watered.

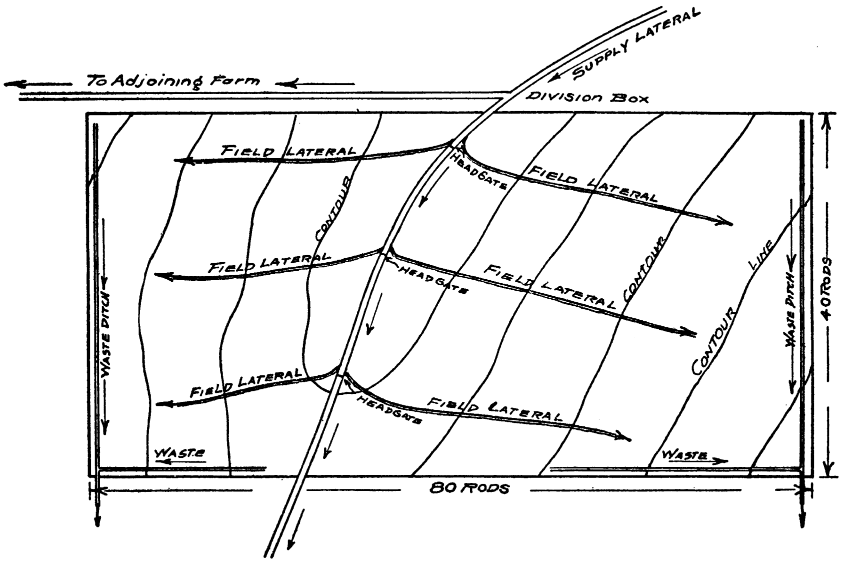

FIG. 14.—A 20-acre alfalfa field near Berthoud, Colo., showing supply lateral, field laterals, contours, and waste ditches.

The chief disadvantages consist in the fatiguing labor required to handle the water, the small area which one man can irrigate in a day, the difficulty in applying water after dark, and the unequal distribution of water on the field unless more than the average care is exercised.

THE FURROW METHOD.

Alfalfa, native meadows, and grain are most commonly irrigated by one of the methods previously described rather than by the furrow method, which is the usual method of irrigating orchards, gardens, root crops, and vegetables. The irrigating of alfalfa from furrows is at present confined to the Yakima Valley, Washington, to portions of the Snake River Valley in southern Idaho, and to comparatively small areas in other States. In the localities named the soil is a fine

clay loam which runs together, puddles when wet, and bakes and cracks when dry. Flooding the surface by any of the customary methods tends to puddle the top layer of soil, which becomes quite hard when the moisture is evaporated. The puddling and baking processes injure alfalfa, and it was with the object of keeping as much as possible of the surface dry that furrows were introduced. When a small stream is permitted to run in the bottom of a furrow for several hours the soil beneath and for some distance on each side becomes wet, while the surface may remain nearly dry.

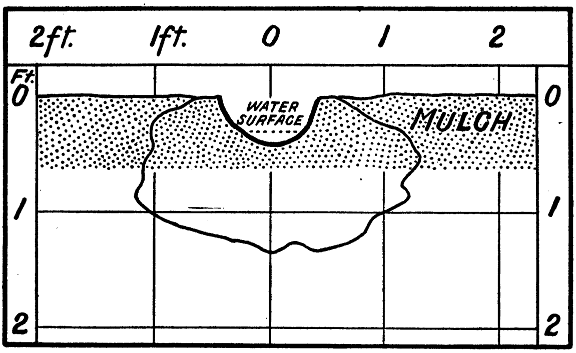

FIG. 15.—Outlines of percolation from furrow 5 inches deep, in seven hours.

This is shown in figure 15, which gives the area wetted from a furrow 5 inches deep in seven hours as determined in one of the orange orchards of southern California.

The alfalfa grown in the Yakima Valley in Washington is practically all irrigated by means of furrows. The grading is usually done by buck scrapers (fig. 16), while a long, rectangular drag similar to the one shown in figure 11 (p. 23) removes most of the surface inequalities that remain after the surface has been leveled roughly by the scraper. The float is made of two 2 by 6 inch timbers about 20 feet long, held in position by crosspieces of the same size 6 feet long.

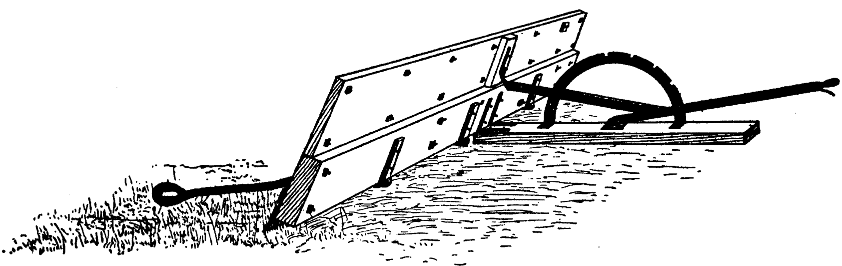

FIG. 16.—Buck scraper.

The common practice is to run the furrows across the entire width or length of a field, and in consequence their length varies from 20 rods or less in small fields to 80 rods in large fields. As a rule, the furrows are too long. Farmers object to cutting up a field by head ditches, but in a climate like that of the Yakima Valley in

midsummer by far the most essential element in plant production is water, and all other considerations should give place to it. It has been shown[a] that water is rarely distributed evenly in furrow irrigation and that much is lost by deep percolation. To increase the length of a furrow beyond 660 feet, or one-eighth mile, not only increases the loss but renders a uniform distribution more difficult to secure. Except in rare cases, this distance should be regarded as the limit for the length of furrows. In light, sandy soils, having a porous gravel stratum beneath, the length may well be reduced to 250 feet.

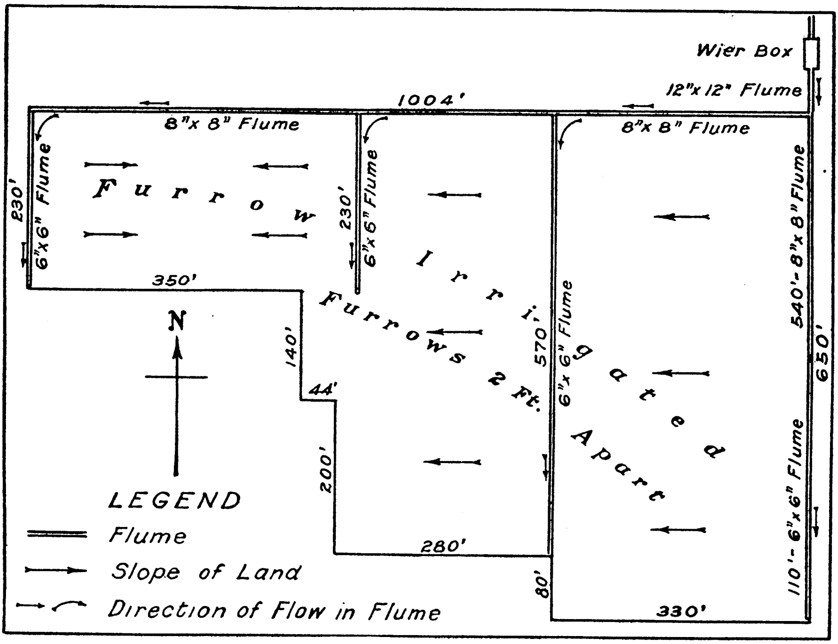

FIG. 17.—Showing tract prepared for furrow irrigation.

Figure 17 shows the manner of dividing an alfalfa field for furrow irrigation at Kennewick, Wash. Lumber head flumes, either 8 by 8 inches or 6 by 6 inches, are placed along the upper boundary of each strip and the direction of the flow in both flumes and furrows is indicated by arrows. Auger holes are bored through one side of the flume flush with the bottom at points where water is to be delivered to the heads of furrows. A short piece of lath revolving on a nail controls the flow from each opening. On steep grades a cleat on the bottom of the inside of the flume nailed on crosswise just below each opening will dam back the water and increase the discharge.

[a] U. S. Dept. Agr., Office Expt. Stas. Bul. 203.

When flumes are considered too costly the water is distributed among the furrows through wooden spouts set in the bank of an ordinary earthen ditch (fig. 18). These head ditches when in operation are divided into a series of level spaces by means of drop boxes which hold the surface of the water at the desired elevation. The spacing of these drop boxes depends on the grade of the head ditch and their cost averages about $2.50 each. Spouts are made usually by nailing together four lath. There is a special lath on the market somewhat heavier than the ordinary one used for plastering buildings, being 0.5 inch thick, 2 inches wide, and 3 feet long. Four of these when nailed together cost about 3.5 cents and each spout in place costs about 6.5 cents. Assuming that they are spaced 4 feet apart the spouts for a square tract of 10 acres would cost

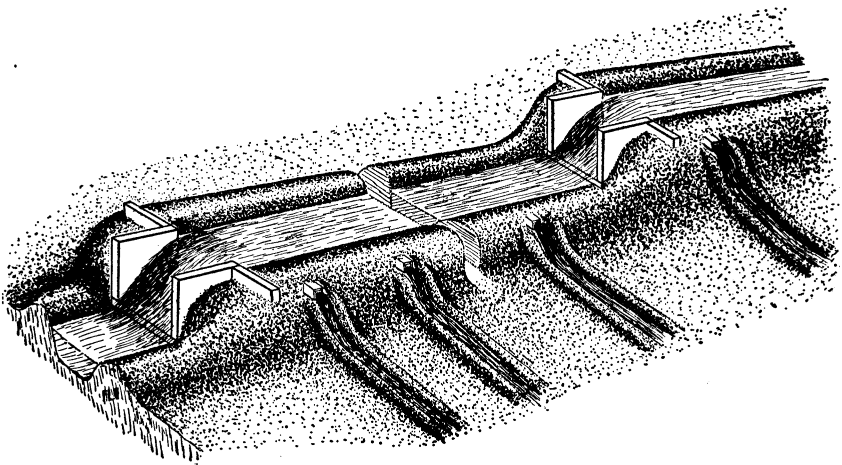

FIG. 18.—Manner of placing tubes in ditch bank for furrow irrigation.

$10.73, or slightly more than $1 per acre. The cost of an ordinary head ditch, with four drops or check boxes, would be about $15 for the same tract, or $2.50 per acre for both, exclusive of grading, smoothing, and leveling. Tin tubes, 0.5 inch in diameter, one to each furrow, have sometimes been used instead of the wooden tubes. When set 0.5 inch below the water surface each tube discharges about 0.1 miner's inch, which is about right for a slope of 3 per cent. The length of the tin tubes is governed by the size of the ditch bank. The tubes are set while the water is in the ditch and are kept at the same level between check boxes. The cost of tin tubes 2 feet long is about $3 per hundred. In many places neither flumes nor tubes are used. Water is taken through cuts in the ditch bank and divided among the furrows as evenly as possible by directing it with the shovel. This practice reduces the cost of preparing the land for irrigation, but it increases the cost of applying water, and does not secure an even distribution among the furrows.

Furrows in alfalfa fields are most commonly made by the use of a marker, or furrowing sled (fig. 19). Sleds with more than two runners are sometimes used, reducing the time required for furrowing, but not producing quite so satisfactory furrows, since an obstruction under one of the outside runners will lift all but the other outside runner out of the ground and leave obstructions in the furrows, which, if not removed, will cause the flooding of the surface. Sometimes a marker is put on the sled to indicate the place for the next furrow.

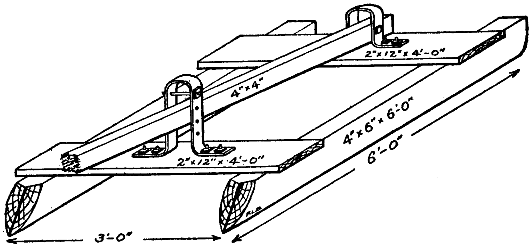

FIG. 19.—Furrower used on experiment farm, Riverton, Wyo.

For the irrigation of most of the crops grown in the vicinity of Twin Falls, Idaho, the feed ditches are laid out across the field as nearly parallel as possible on a grade of 2 to 6 inches to 100 feet and 300 to 500 feet apart. Furrows are made in the direction of the greatest slope and approximately at right angles to the feed ditches. Starting at the upper end, a wooden check is inserted in the ditch at the end of each fall of 12 inches. Thus, if the ditch has a fall of 4 inches to 100 feet the checks are placed 300 feet apart. Each check box is provided with a removable flashboard, which, when in place, backs the water to the next check above and at the same time permits the surplus water to flow over its top to supply the checks below (fig. 20). Lath tubes 16 to 24 inches long are inserted in the lower ditch bank about 3 inches below the water level formed by the flashboards when in place. These tubes are put in while the check is full of water in order that all of each set may be on the same level and that water may be had for puddling. The flow from each tube may be divided among several furrows. Ordinarily a

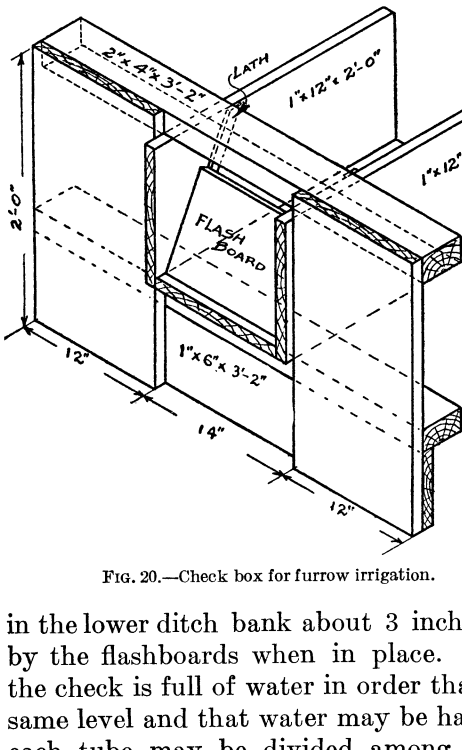

FIG. 20.—Check box for furrow irrigation.

40-acre farm will require about 30 check boxes and 1,800 tubes. Nearly one-half the tubes ought to be 24 inches long to insert near the check boxes where the bank is heaviest, while the remainder may be 16 inches long. The check box shown in the sketch (fig. 20) calls for 17 b. m. feet of lumber, but a serviceable box can be made out of old packing boxes.

Some of the advantages of this method over ordinary furrow irrigation are: A constant head over the inlets of each set of tubes while the surplus passes down the field ditch; the opportunity to use one or all or any combination of checks at the same time, as it is possible to regulate the head and consequently the discharge by

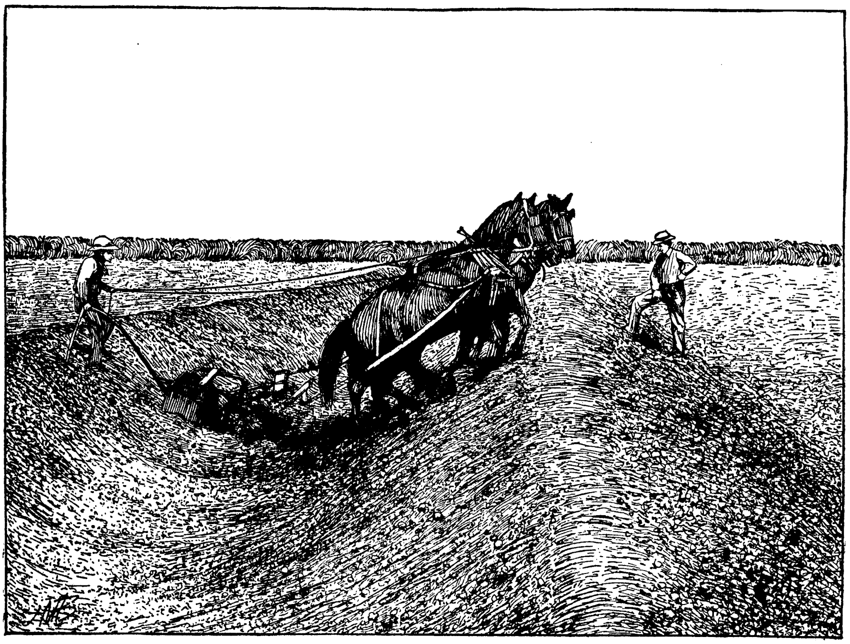

FIG. 21.—Building a supply ditch.

raising or lowering the flashboard; and the automatic character of the water distribution while irrigating.

No fixed rule can be given as to the proper spacing of the furrows or the time water should run in each. In heavy retentive soils the furrows may be 2 to 2.5 inches deep and only 16 inches apart, while in more open soils the furrows may be 48 inches apart.

The amount of water which should flow in each furrow depends on the character of the soil and the slope. It is a common practice in the Yakima Valley to space the furrows 18 to 24 inches apart when the seeding is done, but as the plants grow their roots soon penetrate several feet into the soil and alternate furrows are then abandoned. If the tract contains 10, 20, or 30 acres the furrows run all the way across, if the slope will allow it. Water is frequently

run a quarter of a mile in the small furrows. In furrows 660 to 1,320 feet long in sandy loam, the water has to be kept running continuously for about two days, and consequently there is usually much waste due to deep percolation. In distributing water in furrows it is a good plan to follow the practice of the irrigators of the orange belt in southern California, who turn into each furrow, until the furrows are wet, three or four times as much water as will be permitted to remain, and then reduce the flow.

FARM DITCHES.

The capacity and, to some extent, the location of farm ditches depend chiefly on the method of applying water. In the border method the supply ditch is usually large and so located as to convey a

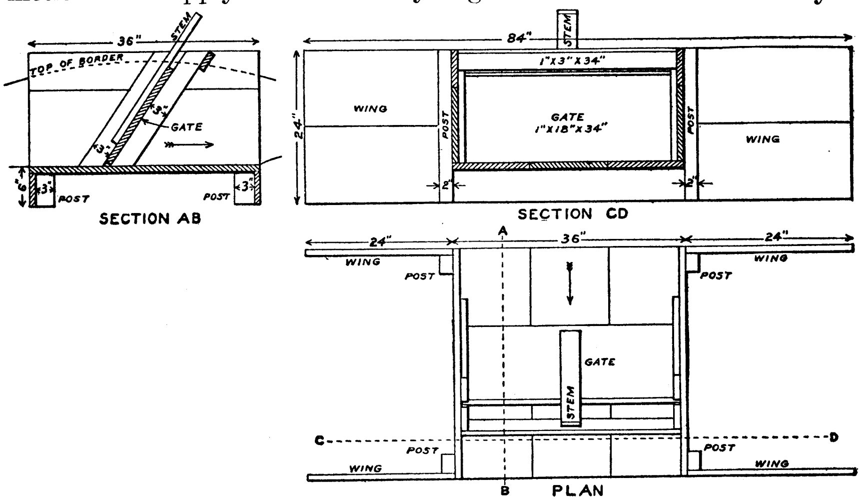

FIG. 22.—A border gate used in Imperial Valley.

sufficient volume of water to the head of each land. In Imperial Valley in California these head ditches, as they are called, have a bottom width of 6 feet and a surface width of 12 to 14 feet. In building a ditch of this size a strip 6 feet wide on the center line of the ditch is plowed 6 inches deep. Then parallel strips, also 6 feet wide, are plowed 8 feet distant from it. Scraper teams then cross and recross these, taking dirt from the plowed strips and dumping it on the unplowed spaces to form the banks (fig. 21). The banks when completed are about 2 feet above the natural surface of the ground, and the bottom of the ditch is 6 to 10 inches below it. When it is deemed best not to create a depression at the outer toe of each embankment, the borrowed dirt is taken from the high parts of the adjacent land.

The water required for each land is withdrawn from the head ditch through a border gate. These are usually made of wood. Figure 22 shows the type of border gate used by F. N. Chaplin, of

Holtville, in Imperial Valley. It requires 49 feet b. m. of redwood' which, at $42 per thousand, makes the lumber cost $2.06. The hardware, carpentry, and setting increase the cost to about $3.25.

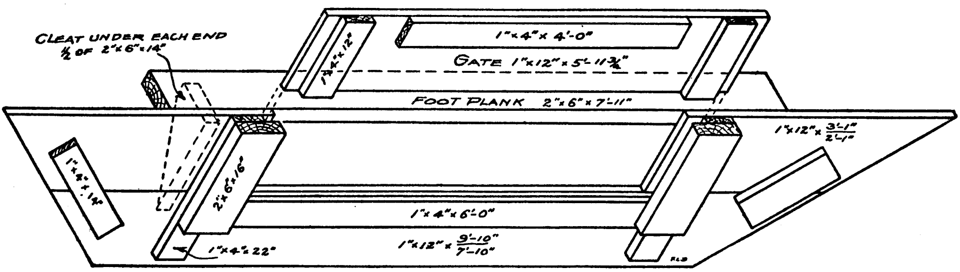

FIG. 23.—Border gate used near Sunset City, Cal.

If it is assumed that 22 gates are needed for a 40-acre tract the cost per acre for the border gates is $1.79. A cheaper border gate is shown in figure 23, which represents the kind used on an alfalfa

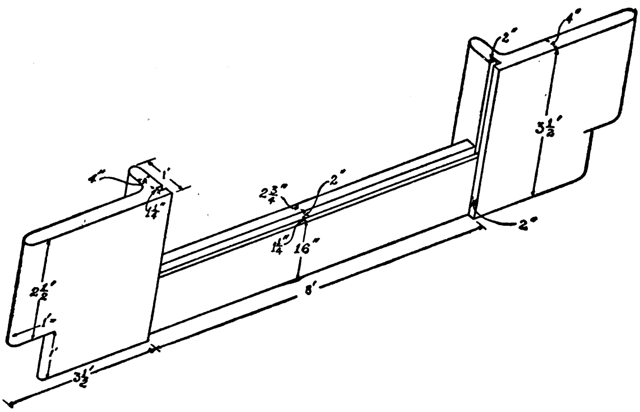

FIG. 24.—Concrete gate used in Yolo County, Cal.

tract at Sunset City, Cal. In some localities concrete is being substituted for wood and figure 24 shows a border gate of this material, quite generally used for the irrigation of alfalfa in Yolo County, Cal.

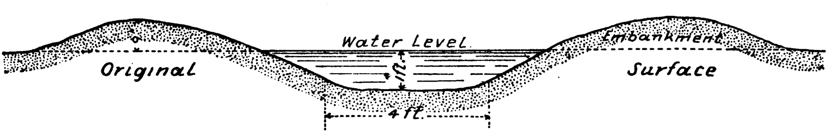

FIG. 25.—Supply ditch with bottom width of 4 feet.

In the check method of irrigation the volumes used do not differ materially from those required to flood the lands in the border method, and the feed ditch for the checks corresponds in size and

capacity to that of the head ditch for borders. Cross sections of common forms of supply ditches are shown in figures 25 and 26. The carrying capacities of these ditches under different grades are given in the accompanying table:

Mean velocity and discharge of ditches with different grades.

SUPPLY DITCH, FIGURE 25.

Grade.			Mean velocity in feet per second.	Discharge.	
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.	Miner's inches under 6-inch pressure head.
$\frac{1}{16}$	0.03	1.58	0.84	4.20	168
$\frac{1}{8}$	.06	3.33	1.08	5.40	216
$\frac{1}{4}$	.13	6.67	1.54	7.70	308
$\frac{3}{8}$	.19	10.00	1.89	9.50	378
$\frac{1}{2}$	.25	13.33	2.20	11.00	440
$\frac{5}{8}$	.31	16.67	2.45	12.20	490
$\frac{3}{4}$	.38	20.00	2.69	13.40	538

SUPPLY DITCH, FIGURE 26.

$\frac{1}{16}$	0.03	1.67	1.03	11.60	464
$\frac{1}{8}$	.06	3.33	1.48	16.70	666
$\frac{3}{16}$	.09	5.00	1.82	20.50	819
$\frac{1}{4}$	.13	6.67	2.11	23.70	950
$\frac{5}{16}$	.16	8.33	2.35	26.40	1,058
$\frac{3}{8}$	.19	10.00	2.58	28.00	1,121
$\frac{7}{16}$	.22	11.67	2.80	30.50	1,260

In flooding land from field laterals two kinds of channels are needed. The larger ones convey the water to the highest corners of

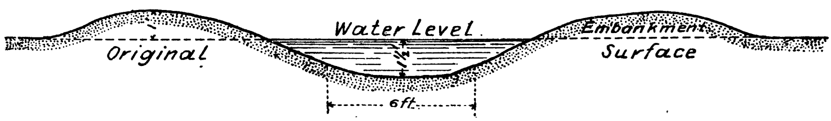

FIG. 26.—Supply ditch with bottom width of 6 feet.

the fields and along one or two borders of each field; the smaller distribute the water over the field. In this method of applying water

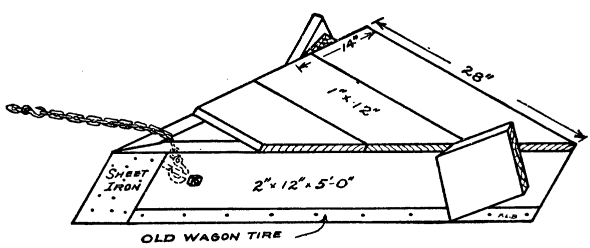

FIG. 27.—"A" crowder.

smaller streams are used than in either the check or border method. Except on large farms the stream seldom exceeds 3 cubic feet per

second, and is usually between 2 and 3 cubic feet. On ordinary grades only a small channel is needed for this volume. Such chan-

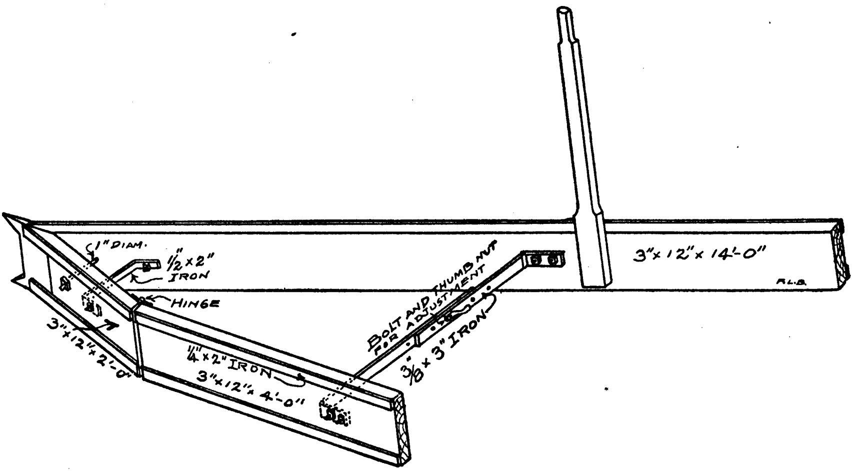

FIG. 28.—Adjustable "A" scraper or crowder.

nels are made by plowing first a strip as wide as the surface of the ditch is to be when full and removing the loose dirt by one of several

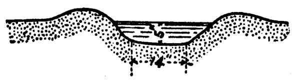

FIG. 29.—Lateral ditch with bottom width of 14 inches.

designs of A crowders, two of which are shown in figures 27 and 28. One of the best implements for making field laterals is a 14 or 16

FIG. 30.—Lateral ditch with bottom width of 16 inches.

inch lister plow on a sulky frame. Figures 29 and 30 show cross sections of lateral ditches made in this way, while figure 31 repre-

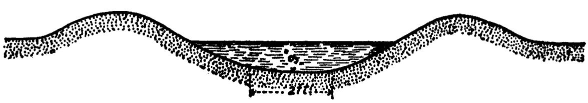

FIG. 31.—Lateral ditch with bottom width of 2 feet.

sents a common type of supply ditch. The effect which grade has upon such channels is shown in the accompanying table, giving discharges of these ditches, with various grades.

Table giving the mean velocity and discharge of ditches with different grades.

LATERAL DITCH, FIGURE 29.

Grade.			Mean velocity in feet per second.	Discharge.	
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.	Miner's inches under 6-inch pressure head.
½	0.25	13.33	1.01	0.67	27
¾	.38	20.00	1.23	.81	32
1	.51	26.67	1.42	.93	37
1¼	.63	33.33	1.59	1.05	42
1½	.76	40.00	1.75	1.16	46
2	1.01	53.33	2.04	1.35	54
2½	1.26	66.67	2.28	1.50	60
3	1.51	80.00	2.50	1.64	61
3½	1.77	93.33	2.70	1.78	71

LATERAL DITCH, FIGURE 30.

¼	0.13	6.67	0.82	0.80	30
½	.25	13.33	1.16	1.00	42
¾	.38	20.00	1.42	1.30	52
1	.51	26.67	1.64	1.50	60
1¼	.63	33.33	1.84	1.70	67
1½	.76	40.00	2.02	1.80	74
1¾	.88	46.67	2.18	2.00	80
2	1.01	53.33	2.34	2.10	86
2½	1.26	66.67	2.61	2.40	96

LATERAL DITCH, FIGURE 31.

⅛	0.06	3.33	0.79	2.08	83
¼	.13	6.67	1.13	3.00	119
½	.25	13.33	1.60	4.20	168
¾	.38	20.00	1.97	5.20	207
1	.51	26.67	2.28	6.00	239
1¼	.63	33.33	2.57	6.80	270

THE SUBIRRIGATION OF ALFALFA FIELDS.

As a general thing, alfalfa is irrigated from the surface downward by one of the methods previously described. There is, however, a small percentage of alfalfa lands, probably not more than 5 per cent of the total, which is irrigated from below. Frequently the seepage water from porous, earthen ditches and the waste water from irrigated areas pass through the subsoil of lower fields sufficiently near the surface to subirrigate them. In other places these seepage waters collect at the lower levels and raise the ground water near enough the surface to supply the plants with the needed moisture. It is questionable if alfalfa growers should place much dependence on this mode of supplying moisture to the plant. What is gained in not having to irrigate is usually more than lost in damage done to both soil and crop by the rise of the ground water. Wherever alkali is prevalent the rise of the ground water near the surface is almost certain to be followed by an accumulation of alkali on the surface.

Again, the fact that alfalfa fields subirrigate is usually nature's way of giving warning that the ground water is rising dangerously near the surface, and observations should be made to determine if the level is above the danger limit. One of the best ways of making such determinations is by means of bored test wells. These are made by boring holes (fig. 1, p. 9) from 2 to 4 inches in diameter in different parts of the field and noting at regular intervals the elevation of the ground water in each. Where the subsoil is a clay or a clay loam no lining will be necessary other than a joint of drain tile or a short wooden tube. Where the subsoil is loose it may be necessary to line the wells with thin galvanized iron or with a wooden box. The wells may be connected by a line of levels, the elevations being taken on the tops of stakes driven beside the wells. These well records, if taken at weekly or even monthly intervals, for several years, will show at a glance not only the position of the ground water, but also its rise and fall throughout the seasons. Whenever it is found that the water table stands for any considerable time at less than 4 feet from the surface there is cause for alarm, and measures should be taken to prevent such an accumulation of seepage waters or to remove the surplus by drainage.

Alfalfa is subirrigated also from the beds of streams. On bottoms the danger is not so great, because there is less alkali present and the height of the ground water is governed by the condition of the stream. It happens often that when the water table is at its highest point the alfalfa plants are dormant or nearly so, and as a result are not so readily injured. Two cases of successful subirrigation from stream channels are here cited by way of illustration.

On the farm of J. A. King, located on the second bottoms about 5 miles northeast of Boulder, Colo., the water table is 10 to 12 feet below the surface. An average yield of alfalfa of 4 tons per acre has been obtained for the past nine consecutive seasons from this farm without any perceptible deterioration. The crop was irrigated the first year, but after that the roots had evidently reached water and continued to draw their supply from that source.

On the Arkansas River south of Cimarron, Kans., John Bull has an alfalfa field of over 50 acres which is subirrigated. The water table is found at a depth of 6 to 8 feet, and the yield is usually 1 ton at each cutting. It is cut three to five times each season, and in some years one crop of seed and two crops of hay are raised.

Throughout the arid region there are a few localities where subirrigation is quite generally practiced. Perhaps the most notable of these is to be found in the vicinity of the towns of St. Anthony and Sugar City, in the upper Snake River Valley in Idaho. This subirrigated district comprises an area of about 60,000 acres. A characteristic of the subsoil of this large area is that it is composed of sand

and gravel, sometimes mixed with cobble rock to the lava bed rock, which is found at depths varying from a few feet to 90 feet. The surface soil around St. Anthony is a dark-colored gravelly loam 2 to 4 feet deep. On the Egin Bench it is a dark sandy loam 1.5 to 5 feet deep, while around Sugar City it is a clay loam 4 to 6 feet deep. The land slopes to the south and west at the rate of about 10 feet to the mile.

At first ordinary ditches were built and for years attempts were made to irrigate the land by the usual methods. These failed, how-

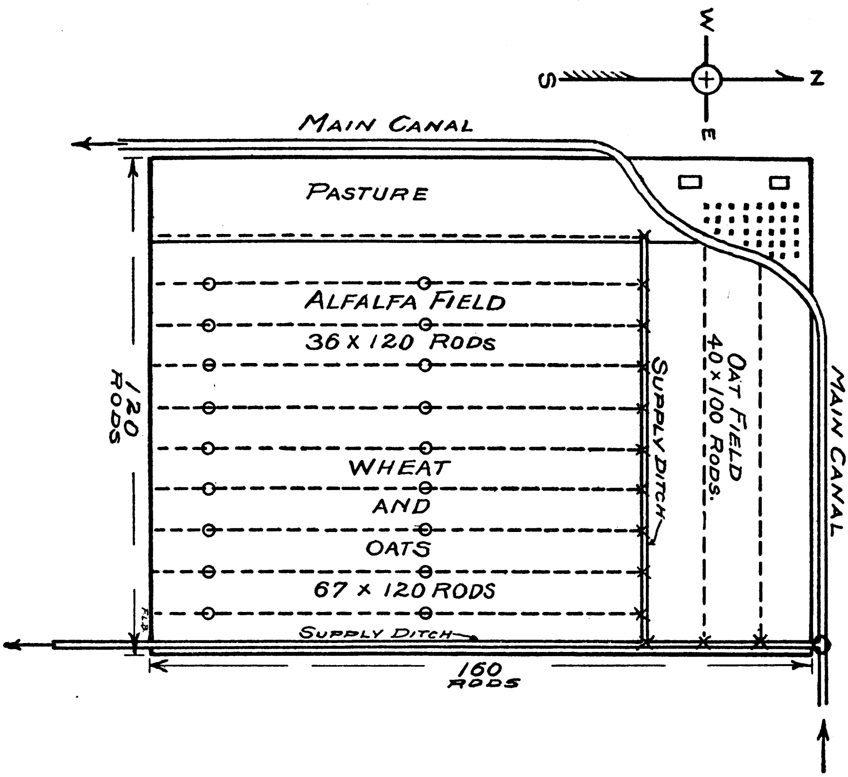

FIG. 32.—One hundred and twenty-acre subirrigated farm of C. H. DeCamp, 12 miles south of St. Anthony, Idaho.

ever, since all the water turned into the ditches soon sank into the porous subsoil beneath. In time much of this subsoil filled up with water, due to an impervious lava bed rock, and the top layers of soil became moistened from below. This condition led the farmers to adopt a new method of irrigation, a type of which is shown in figure 32. On a farm of 120 acres, the property of C. H. DeCamp, located 12 miles south of St. Anthony, Idaho, the main canal passes along the north and west boundaries. From this a supply ditch is run which feeds the smaller laterals. These laterals are shallow ditches

about 3 feet wide and 6 inches deep and divide the farm into strips. On the majority of farms the laterals do not exceed 1,320 feet in length and are spaced 100 to 300 feet apart. On this particular farm their length is increased beyond the average and their width decreased. In this mode of irrigation no water is spread over the surface; the laterals merely distribute 15 to 20 miner's inches each to different parts of the field, where it soon joins the ground water by sinking through the bottoms of the shallow ditches. The land is planted in the early spring when the ground water is low, and then water is turned into the ditches and kept in day and night until the ground water rises sufficiently near the surface to supply the needed moisture to the roots of plants. Thereafter the height of the ground water is regulated by the amount of water turned into the supply ditch. The rise and fall of the ground water is determined by means of small boxes set in the ground 3 to 5 feet deep, as indicated by the circles in figure 32. Twenty to 30 boxes are usually required for each 80-acre farm. All water is turned out of the main canal prior to September 15 to permit the land to dry out for the harvesting of such crops as sugar beets, potatoes, etc. When the crops are removed, a small stream is left running in the main canal all winter; but notwithstanding this supply, the ground water usually falls from 6 to 20 feet below the surface during the fall and winter months. This somewhat novel method of applying water has led to the adoption of a rotation of crops which seems to suit both water and soil conditions. Alfalfa does not do well after the third year. This is chiefly due to the height at which the ground water is kept during the spring and summer months. Then, too, the soil is lacking in humus. These conditions have led the farmers to grow alfalfa on a tract for two or three years and then to turn the alfalfa under and raise grain, sugar beets, and potatoes for the next three years. Under this rotation the yields per acre on well-managed farms are 40 to 60 bushels of wheat, 75 to 110 bushels of oats, 50 to 90 bushels of barley, 300 to 500 bushels of potatoes, 15 to 20 tons of beets, and 4 to 6 tons of alfalfa. The land sells for $100 to $150 an acre.

AMOUNT OF WATER REQUIRED.

Alfalfa requires more water than most crops. This is readily accounted for by the character of the plant, the rapidity with which it grows, the number of crops produced in one season, and the heavy tonnage obtained.

As a result of careless practice there is a lack of uniformity in the quantity of water used, the volumes applied frequently being far in excess of the needs of the crop. The majority of the records collected and published by this Office show a yearly duty of water for alfalfa ranging from 2.5 to 4.5 feet in depth over the surface, while

in quite a large number of cases the volumes applied would have covered the area irrigated to depths of 6 to 15 feet.

From the large number of measurements made on the duty of water it is possible to select some that possess great value, since they indicate what can be accomplished with a given quantity of water.

During the season of 1904 careful measurements were made by C. E. Tait, of this Office, of the amount of water used on alfalfa fields in the vicinity of Pomona, Cal. The rainfall at Pomona for the winter of 1903–4 was much below the normal and amounted to about 9.1 inches.[a] The quantity of irrigation water applied by pumping averaged 2.3 feet in depth and the yield of cured hay averaged from 1 to 1.5 tons per acre per crop, five or six crops being common. These figures are corroborated by many others collected in southern California. Perhaps in no other locality of the arid region is a greater tonnage of alfalfa obtained, yet in a climate of scanty rainfall having a long, dry, hot summer only a comparatively small amount of water is used. About a third of the 9,000 acres irrigated by the Riverside Water Company is in alfalfa and for the past seven years the average depth applied has been 2.31 feet, while the depth of rainfall and irrigation water combined has averaged 3.18 feet.

In 1903 the writer, when director of the Montana Experiment Station, applied different depths of water to seven plats of alfalfa with the results given in the following table. It will be seen that a high tonnage for so short a season as prevails in Montana was obtained from plat 5 with the use of 2 feet of water. By irrigating plat 6 seven times, and plat 7 eight times, it was possible to increase the yield to the amounts stated. The results of this experiment seem to confirm the best practice of southern California, which may be summed up by stating that in localities having an annual rainfall of about 12 inches remarkably heavy yields of alfalfa may be obtained from the use of 24 to 30 inches of irrigation water, providing it is properly applied.

Quantities of water applied to alfalfa and yields secured, Montana Experiment Station.

Plat number.	Depth of irrigation.	Depth of rainfall.	Total depth.	Yield per acre of cured alfalfa.
	Feet.	*Feet.*	*Feet.*	*Tons.*
1	0.5	0.70	1.20	4.61
2	None.	.70	.70	1.95
3	1.0	.70	1.70	4.42
4	1.5	.70	2.20	3.75
5	2.0	.70	2.70	6.35
6	2.5	.70	3.20	7.20
7	3.0	.70	3.70	7.68

[a] U. S. Dept. Agr., Weather Bureau, Climate and Crop Service, California, Ann. Sums., 1903 and 1904.

THE PROPER TIME TO IRRIGATE ALFALFA.

The general appearance, and more particularly the color of the plant, are the best guides, perhaps, as to when water is needed. When healthy and vigorous, alfalfa is of a light-green color; but when the supply of moisture is insufficient the leaves take on a darker and duller shade of green and begin to droop, and unless water is provided both stems and leaves wither and die. Another test is to remove a handful of soil 6 inches or so beneath the surface and compress it in the hand. If it retains its ball-like shape after the pressure has been removed and shows the imprints of the fingers, the soil is sufficiently moist, but if it falls apart readily it is too dry. In connection with such tests it is well to bear in mind that they are more or less influenced by both soil and climate. It is therefore necessary to observe the growth of the plant closely on all new alfalfa fields to determine if possible how far such tests may be relied upon, the chief object being to maintain at all times as nearly as practicable the proper amount of moisture in the soil surrounding the roots of the plants to prevent a checking of their growth.

Alfalfa commonly receives careless treatment at the hands of western irrigators. When water is available and is not needed for other crops it is usually turned on the alfalfa fields or meadows whether these need it or not. There is no question that yields of alfalfa might be considerably increased if more care was used in finding out when to apply water. In each kind of soil and under any given set of climatic conditions there is a certain percentage of soil moisture which will give the best results. Under the present unskillful practice it is impossible to maintain uniform soil-moisture conditions for any length of time. The soil is apt to receive too much or too little water, or else it is deluged with cold water at a time when it needs only heat and air. The number of irrigations required depends upon the depth and nature of the soil, the depth to ground water, the number of cuttings, and the rainfall, temperature, and wind movement. Other things being equal, more frequent waterings are required in the warm sections of the South than in the cooler portions of the North. The number of irrigations per year for alfalfa ranges from 4 in Montana and Wyoming to as many as 12 in parts of California and Arizona. In localities where water is scarce during part of the season the number of waterings as well as the amount used each time depends on the available supply. It is a common practice to apply frequent and heavy irrigations in spring when water is abundant and to water less often and more sparingly when the supply is low.

WINTER IRRIGATION OF ALFALFA.

When water is applied either to bare soil or to crops outside of the regular irrigation season it is termed winter irrigation. The practice thus far has been confined largely to the warmer parts of the arid region. It has become well established in Arizona and California and is being quite rapidly extended to parts of Oregon, Kansas, and the Rocky Mountain States.

Experience has shown that a deep retentive soil is capable of storing a large quantity of water. On account of the fluctuation of western streams of all kinds, from the small creek to the large river, the greatest flow of water often comes at a season when there is least demand for it. In a few localities adequate storage facilities have been provided to retain the surplus, but as a rule it is allowed to go to waste. The passage of so much waste water led to the introduction of winter irrigation and in nearly every case the results have been satisfactory. The chief differences between winter and ordinary irrigations are the larger volumes used, the crude manner of conveying and applying the water, and the dormant or partially dormant condition of the plants at the time of irrigation.

In Fresno County, Cal., water is turned into the canals in January and February. The large canals of the Modesto and Turlock districts run more than half a head during the latter half of February. This is the rainy period in both these localities and the soil is usually too wet for plant growth, but water is applied to alfalfa fields to fill up the subsoil so as to provide a surplus for the rainless summer when water is scarce.

Besides furnishing a supply of much-needed moisture, winter irrigation, when conditions are favorable, prevents winterkilling and improves the mechanical condition of the soil.

WINTERKILLING OF ALFALFA.

The winterkilling of alfalfa is confined chiefly to the colder and more elevated portions of the Rocky Mountain region and to the northern belt of humid States. Damage from cold is rare in Arizona and in California it is confined to young plants. In both the Sacramento and San Joaquin valleys of the latter State the seed is frequently sown in midwinter and the slight frosts which occur occasionally in December and January in both these valleys are severe enough to kill very young plants. The belief is common that the plants are safe after they have put forth their third leaf.

In the colder portions of Montana, Wyoming, Colorado, Utah, and the Dakotas alfalfa is apparently winterkilled from a variety of causes

and sometimes from a combination of causes. The percentage of loss around Greeley, Colo., has been placed at 2 per cent per annum. In this locality and throughout the Cache la Poudre Valley in northern Colorado most of the winterkilling is done in open, dry winters and is quite generally attributed to a scarcity of moisture in the soil. In the winter of 1907 considerable damage was done to the alfalfa fields around Loveland, Colo., on account of the long dry spell in midwinter. The old alfalfa fields suffered most. It was the opinion of the farmers that a late fall irrigation would have prevented the loss.

Near Wheatland, Wyo., the higher portions of the fields suffer most damage in winter, and here also the cause is said to be lack of moisture in the soil, combined with the effects produced by cold and wind.

At Choteau, in northern Montana, a farmer watered, late in the fall, part of an alfalfa field which was 2 years old, and it winterkilled, while the unwatered portion escaped injury. This and other evidence along the same line which might be given go far to demonstrate that under some conditions too much moisture is as detrimental as too little.

Probably the chief cause of the winterkilling of alfalfa is alternate freezing and thawing. The damage from this cause is greatly increased when any water is left standing on the surface. A blanket of snow is a protection, but when a thin sheet of ice forms over portions of a field the result is usually fatal to plants. The bad effects of alternate freezing and thawing on alfalfa may be observed at the edge of a snow bank. This crop is likewise injured by the rupture of the tap roots caused by the heaving of the soil.

From present knowledge of the subject, the means which may be used to protect alfalfa fields from winterkilling may be summed up as follows: Where both the soil and the air are dry the plant should be supplied with sufficient water for evaporation, but the land should be drained so thoroughly that none of the top soil is saturated; a late growth should not be forced by heavy irrigations late in the growing season; if the soil is dry, irrigate after the plants have stopped growing; and the latest growth should be permitted to remain on the ground, unpastured, as a protection.

It may be stated in conclusion that the loss to the farmer from the winterkilling of alfalfa is not as great as might appear at first. The damage is done in winter, and there is ample time to plow the plants under and secure another crop, which is usually heavy, owing to the amount of fertilizers added by the roots of alfalfa. The Montana farmer who increased his average yield of oats from 50 to 103 bushels per acre by plowing under winterkilled alfalfa illustrated this point.

SEEDING ALFALFA ON LAND TO BE IRRIGATED.

In Utah the most common practice now is to sow alfalfa without a nurse crop. From 12 to 18 pounds of Utah-grown seed is put in with a 6-inch press drill to a depth of $\frac{3}{4}$ to $1\frac{1}{2}$ inches during the first half of April. Irrigation before seeding is not necessary, as the soil is usually moist and contains sufficient moisture to support the plants until they attain a height of 6 to 10 inches. At this stage the alfalfa and the weeds are cut about 4 inches above the surface, the cutter bar of the mower being raised for that purpose, and the cuttings are left on the ground. Water is kept off after cutting until the crop begins to suffer. It is believed that when young plants lack moisture they will strike their taproots deeper into the soil in quest of water, and in this way develop a better root system than they would under frequent and copious irrigations. When alfalfa is sown with a nurse crop, oats is preferred. From 10 to 15 pounds of alfalfa seed is sown with 3 pecks to 1 bushel of oats.

In the upper Snake River Valley, in Idaho, alfalfa is usually preceded by a grain crop. The stubble is plowed 6 to 9 inches deep in the fall, and early in the spring it is double-disked, harrowed, and smoothed. From 8 to 20 pounds of seed is then drilled in 0.75 inch to 1.5 inches deep in rows 6 inches apart. When oats is used as a nurse crop it is seeded first, 80 to 100 pounds per acre being used. From 8 to 12 pounds of alfalfa seed are then drilled in, in the opposite direction. Some farmers use a combination drill which seeds both at the same time. When no nurse crop is used the alfalfa plants are clipped when they reach a height of 8 to 12 inches. This is necessary to hold the weeds in check and to cause the plants to stool.

In the Yakima Valley, March and April are preferred for seeding alfalfa, both on account of the climate and the abundant water supply of that period. The ground is plowed deep, graded, smoothed, and harrowed. From 10 to 20 pounds of seed are then put in with a broadcast seeder and harrowed lightly. The furrows are then marked off and irrigation begins. The ground is kept moist constantly until the young plants are fairly well established. The use of so much water at the start is due largely to the tendency of the soil to bake if allowed to become dry.

The alfalfa growers of Montana are about equally divided in opinion as to the advantages of using a nurse crop. Those who seed grain with alfalfa claim that they get more out of the land the first season, while those who are opposed to this practice believe that the injury done to the alfalfa plants by the grain crop extends through several years and that the small gain of the first year is more than offset by the lessened yields of alfalfa in subsequent years.

In northern Colorado, rotation of crops is practiced and alfalfa seed is sown with a nurse crop, usually wheat or barley. The seed is drilled early in the spring with a common force-feed press drill equipped with an auxiliary seed box for alfalfa seed, which is scattered broadcast between the grain rows and covered by the disk wheels of the press drill. From 12 to 20 pounds of alfalfa seed are sown. Irrigation before seeding is not practiced. There is, as a rule, sufficient rainfall to furnish both crops with moisture until the grain is ready to head out and the alfalfa is 4 to 6 inches high, when the field is irrigated.

At Wheatland, Wyo., various methods of seeding alfalfa are in use, but the one which gives the best results may be described as follows: Drill in 1 bushel of barley to the acre; then in a week or ten days cross drill the field, sowing 12 to 15 pounds of alfalfa, setting the press drill so that the seed will be covered 0.75 inch to 1.5 inches deep.

In Yuma and other valleys of Arizona, October planting is preferred. Frequently in this dry climate the land is irrigated before being seeded. It is cultivated, then seeded and harrowed. In the dry-planting method the seed is sown broadcast on the dry soil, harrowed lightly with a brush drag, and then irrigated. A second irrigation is necessary in about eight days to break the surface crust.

In California the treatment given to alfalfa in the first stage of its growth varies somewhat with the locality; in Kern County the seed is sown from December to April, inclusive, with a preference for February and March seeding. If the soil is dry it is first irrigated. In the Modesto and Turlock districts more or less seeding is done throughout the winter months, but the greater part is seeded in March and April, just before the dry season begins. From 30 to 40 acres can be seeded in a day with a hand-broadcasting machine if the operator sits in the back of a wagon which is driven over the field. Eighteen pounds of seed to the acre is the average amount sown.

RISE OF GROUND WATER AND ITS EFFECTS ON ALFALFA.

In their natural state the typical soils of the arid region are characterized by the depth to water and their looseness and dryness. The diversion and use of large quantities of water in irrigation soon change some of these natural conditions. A part of the flow in earthen channels escapes by seepage and still larger quantities percolate into the subsoil from heavy surface irrigations. The waste water from these and other sources collects in time at the lower levels and raises the ground-water level. This rise is usually noticed first in wells, a permanent rise of 5 feet in a year being not uncommon.

This rise of the ground water is an advantage, provided the water table does not rise too high. It lessens greatly the cost of sinking

wells, less water is needed in irrigation, and it furnishes a reservoir from which water can be pumped to supply other lands.

It is not until the water level encroaches upon the feeding zone of valuable plants that its injurious effects are felt by the farmer. Its near approach to the surface may prove so disastrous that its upward trend should be noted with the greatest care. Perhaps the best means of providing for such observations is the use of test wells, referred to on page 36.

There is some difference of opinion as to what depth below the surface marks the danger line for alfalfa. It has been shown by Doctor Loughridge, of the University of California, and by other soil physicists that water may be withdrawn by capillarity from soils to depths varying from 4 to nearly 5 feet, depending on the character of the soil. This fact has an important bearing on the subject, because when the ground water is brought to the surface and evaporated the salts held in solution are deposited at or near the surface. If these salts contain much sodium sulphate, or even sodium chlorid, all of which are usually grouped under the common term alkali, the crust formed by them will in time destroy the alfalfa. It may be stated, therefore, that when alkali is present in harmful quantities in the ground water it should not be allowed to rise nearer than 4 feet below the surface.

The percentage of harmful salts in the ground water is usually determined by the chemist of the nearest agricultural experiment station, but when an accurate test can not be made in the laboratory the farmer may make a practical test in the following manner, in accordance with a suggestion made by A. T. Sweet, of the Bureau of Soils of this Department:

Take three pots containing equal amounts of soil and plant the same number of grains of wheat in each. Water each pot with equal quantities of water. In No. 1 apply fresh water, in No. 3 ground water, and in No. 2 an equal amount of each kind. The injury, if any, caused by the ground water will be indicated by the longer time required for the plants to appear above the surface, the smaller number of plants to germinate, and their general appearance.

In soils free from alkali but saturated with water there is not the same necessity for holding the ground water continuously below a so-called danger line. In parts of Kern County, Cal., the ground water sinks to 8 feet below the surface of alfalfa fields in summer, but rises to within 1.5 feet of the surface in winter. There is no indication of root rot and the plants have retained their full vigor. Numerous cases might be cited to show that the rise of water to within a foot or two of the surface for comparatively short periods of time does little injury to the plants. On the other hand, wherever water stands continuously during the irrigation season within a few feet of the surface it is pretty certain to kill alfalfa in three years or less.

THE INJURIOUS EFFECT OF SILT ON ALFALFA AND THE BENEFITS TO BE DERIVED FROM DISKING.

The silt-laden waters of the rivers of the Southwest during periods of high water in time form a crust over the surface of irrigated alfalfa fields. The soil formed by such rivers is naturally impervious, and when a coating of fine sediment is deposited around the plants the effect is injurious, particularly to young plants, which may be killed as a result, notwithstanding the fertilizing value of the silt. In irrigating with water carrying much silt the larger and heavier particles are deposited in the channels which convey the water from the streams, while the finer and lighter particles are carried to the fields. These fine particles cement together and form so hard a crust when dry as to exclude both air and moisture from the soil.

Engineers may in time devise a practical remedy for this evil by building settling basins and storage reservoirs, but at present the tendency of many officers of canal companies is to increase the grade of the channels so as to carry the greater part of the silt to the fields. This does not solve the problem; it merely shifts the burden to the water users. To such, disking the surface at the proper time has proved the most efficient remedy. An effort is made to secure well water or clear ditch water while the alfalfa is young and later to counteract the bad effects of muddy water by the free use of the disk.

Disking alfalfa is quite generally practiced now throughout the West. It is generally done in the spring as soon as the ground is hard and firm and before the growth has started. When a field is disked a second time in the same season it is done when the stubble is short, just after the removal of the crop. The disks should be set nearly straight, so as to stir but not overturn the soil. The spring-tooth harrow is used also, but its tendency is to tear up the ground too much. Perhaps the best implement for this purpose is the spike disk harrow or alfalfa renovator, as it is sometimes called, in which spiked wheels are substituted for the ordinary concave disks.

Disking not only breaks up the impervious layers formed by muddy water, but it splits the old root crowns, thickens the stand, destroys weeds, checks evaporation, and mixes the dead leaves of previous crops with the top layer of soil.

PASTURING IRRIGATED ALFALFA.

Only a small part of the total acreage in alfalfa is pastured throughout any one season, but a large part is pastured during short periods, usually in the fall. Since the plants are easily injured and killed

by stock when the ground is wet and soft, stock should be kept off for a time after irrigation. On this account it is a good plan to have the pastures fenced into three equal parts and pasture but one at a time. The inclosures should be alternately pastured, irrigated, and the stand allowed to reach a height of 8 inches or so before stock is turned in again.

PRODUCTION OF ALFALFA SEED UNDER IRRIGATION.

The large area which is seeded to alfalfa each year creates a demand for alfalfa seed. Good seed is grown now in every irrigated State in the West, and the contention that it can not be produced successfully under irrigation is unfounded. The use of too much water is doubtless the cause of many failures. Any one of the crops may be saved for seed, but it requires about twice as long to produce a seed crop as it does a hay crop, owing to the extra length of time required for the seed to ripen, and the different crops do not yield equally well. The more general custom is to save the second crop for seed, and where this is done it is recommended that the first crop be irrigated as usual for hay, and that water should be applied very sparingly, if at all, to the seed crop. Where the same amount of water is used as for hay the growth is rank and rapid, and hay rather than seed is produced.

PROFITS TO THE IRRIGATOR.

The feeding value of alfalfa is so high that the greatest profits can be obtained usually by feeding it to farm animals. When sold in the stack the net profits vary between somewhat wide limits. From the three tabulated statements which follow some idea may be given of the profits to the grower under skillful practice.

Profits from alfalfa growing.

Yakima Valley, Wash.:		
Annual cost of water per acre	$1.50	
Cleaning and repairing farm ditches	.50	
Annual taxes	.75	
Cost of applying water during the season	3.50	
Cost of harvesting and marketing, 7 tons at $2	14.00	
Annual depreciation of hay tools, irrigation structures, etc	1.00	
		$21.25
Average yield of 7 tons, at $7		49.00
Annual profit per acre		27.75

Annual interest on investment 22.2 per cent, on a basis of land and water right valued at $125 per acre.

Parma and Roswell districts, Idaho:

Annual cost of water per acre	$0.50	
Cleaning and repairing farm ditches	.40	
Annual taxes	.60	
Cost of applying water during season	1.50	
Cost of harvesting and marketing, 7 tons at $1.75	12.25	
Annual depreciation of hay tools, irrigation structures, etc	1.00	
		$16.25
Average yield of 7 tons, at $5 per ton		35.00
Annual profit per acre		18.75

Annual interest on investment 18.75 per cent, based on land and water right valued at $100 per acre.

San Joaquin Valley, Cal.:

Annual cost of water per acre	$1.90	
Annual cost of applying water per acre	2.20	
Cleaning and repairing farm ditches	.50	
Annual taxes	1.00	
Cost of harvesting and marketing, 7 tons at $2 per ton	14.00	
Annual depreciation of hay tools, irrigation structures, etc	1.00	
		$20.60
Average annual yield of 7 tons, at $7 per ton		49.00
Annual profit per acre		28.40

Annual interest on investment 16.2 per cent, based on land and water right valued at $175 per acre.

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